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Surgery

A Case Based Clinical Review
Second Edition

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To my wonderful wife and fellow surgeon, Kelly, who has always supported me; to my five children, Nick, Michael, Emma, Sophia, and Andrew, who have always made coming home a pleasure; and to all the students over the last two decades who have inspired me to teach.

Christian de Virgilio

To my two biggest mentors – Dr. Christian de Virgilio and Dr. Jeffry Nahmias – thank you both for your instrumental roles in shaping my career and allowing me to truly enjoy waking up everyday to come to the hospital. To my amazing wife, Rebecca, and my future little surgeon, Ella Sophia, thank you for being my biggest supporters.

Areg Grigorian

Foreword

I am delighted to write the foreword for the second edition of *Surgery: A Case Based Clinical Review* edited by Christian de Virgilio and Areg Grigorian.

I was honored to write the first one, and the book has had such impact since its publication in 2015 – it has been adopted by several medical schools, and it is in the top five of Springer’s medical books and among the top seven on Amazon! The book is meant for short chapter reads organized into sections with shelf questions at the end of each section to quickly assess one’s understanding of the important content.

Dr. de Virgilio was a third-year medical student on a pediatric surgical rotation when I was the senior resident. He was a fabulous student and went on to be a vascular surgeon – just like I did! He is a fabulous teacher and role model. Now, he is professor of Surgery, UCLA School of Medicine, chair of the Department of Surgery at Harbor-UCLA Medical Center, as well as co-chair of the College of Applied Anatomy.

This medical school textbook is such a treasure for medical students. The chapters begin with a patient

story followed by the pertinent facts needed on the history and physical examination – and, then, the student can learn to design the work-up, make the diagnosis, and manage the surgical problem. The preparation is essential to be able to answer the shelf examination questions which follow – all of this getting the medical student ready to master the information and do well on their examination in surgery.

As a dean of a medical school and a vascular surgeon, I am delighted that this book has served the medical students so well. I still see patients, perform surgery, and teach medical students, and, therefore, a book like this one is perfect! Someone taught us – therefore, we should teach as well!

» Life is an opportunity for us to contribute something that outlasts us and makes the world a better place.

–Apoorve Dubey

Teaching makes the world a better place. Go do that!

Julie Ann Freischlag, MD
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Preface

We are grateful to have heard from students around the country that our first edition was valuable for their surgery clerkship. As we are always striving to improve, we thank students for their valuable comments and have incorporated their feedback into the second edition to make it even better. At the same time, we've been sensitive to maintaining our goal of making the entire book "readable" over the course of a relatively brief third-year surgery clerkship. Thus, for this second addition, we've added several key chapters while condensing and combining others. As with the first edition, we've assembled a team of collaborators that include numerous surgery program directors, surgery clerkship directors, and various award-winning surgical educators. We've also included several medical students who were handpicked for their outstanding performance.

The goal of our book is to help you learn the essentials of surgery in the most efficient way possible. We feel our book will help you excel on the shelf exam, shine on the wards, think through the most commonly tested clinical vignettes, and develop your own deductive reasoning so that you make a great impression on your surgery clerkship. Additionally, each section is now followed by a series of questions that are intended to mimic the style of questions you will find on the actual NBME shelf exam.

The start of the third year of medical school is terrifying. You're suddenly thrust into a hospital, where you meet a new team of residents and faculty, meet patients, learn a new language (medical abbreviations), learn an electronic health system, and are expected to somehow shine even though you're the least experienced and least knowledgeable. Once you finally get acclimated, you might get moved to another rotation in another specialty (sometimes even to another hospital), forced to start the orientation once again. At the same time, you're required to attend lectures and prepare for a final examination that may influence your ability to get a future residency. It's no doubt an extremely stressful time, but, at the end of the year, you will marvel at your professional growth and realize that being in the hospital with real patients is far better than being in a classroom all day. Also, you can

take solace in the fact that all your evaluators (e.g., residents and attendings) were at one point in their careers medical students like you. We hope our book gives you all the high-yield, test-relevant facts in an efficient and easy-to-understand manner so you can focus on what is important – how to be a great doctor!

Before discussing how to use our book, we want to share a few pearls about the surgery clerkship. First the "dos." Surgery is a team-based discipline. Always look for ways to help your team. Take an active role. Strive to make yourself irreplaceable, but do so with humility. Treat others like you would your family (assuming you get along with them). Be an effective communicator. Ask a lot of questions (but make it clear from your questions that you've been reading). Ask how you can help. Now the "don'ts." Don't be arrogant. Don't try to upstage your co-student or intern. And finally, don't worry! If you work hard, display enthusiasm, and take an active role, people will notice! You'll also be surprised to discover that most surgeons enjoy teaching (and aren't as mean as portrayed on TV). And you may even get bit by the surgery bug (we hope)!

Now let's move on to how to use this book. The book is case-based and is in a short question-and-answer format. A risk of a case-based book is that you only learn that one specific case. To prevent falling into such a pitfall, we've also included pertinent differential diagnoses for each case and discuss how to distinguish them. We've tried to limit anatomy and pathophysiology to those that are clinically relevant. We've tried to exclude most cancer staging systems, as these constantly change, are hard to memorize, and are infrequently tested. We've tried to arrange the management in a "what's the next step" format, as such questions are frequently asked. We've purposely avoided too many details about specific aspects of surgical procedures as those are beyond the scope of a student. For those that want a bit more, we've added "areas where you can get in trouble," which are pitfalls in the diagnosis or management, and "areas of controversy." At the end of each chapter, there is a Summary of Essentials that permits a quick review. Finally, we've created questions and answers to follow

each section (with an emphasis on why the wrong answers are wrong). It's important to realize that the questions are *not* intended to test your understanding of the reading. Rather, many of the questions are meant to supplement the reading by testing important topics that couldn't be covered (so don't be discouraged if you miss a lot of them!).

Our advice is to strive to read the whole book during your rotation. Read all the chapters in one section, and then do the supplement questions for that section. We've purposely made each chapter relatively short, so that you should be able to read

each one in 20–30 min (or less). And, you should be able to read four to five chapters per week.

We're confident our book will help you during your surgery clerkship as well as for the shelf exam. We also realize that no single resource can do it all (including this book).

We hope you enjoy our book as much as we enjoyed writing it! We'd love to get your feedback. Feel free to email us on cdevirgilio@lundquist.org and agrigori@uci.edu or follow on Twitter @drdevirgilio. Best of luck on your rotation and in your (surgical) career!

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in our book project and quickly embraced it, and Connie Walsh, Developmental Editor at Springer, who patiently put up with our constant emails, phone calls, and numerous revisions.

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Acute Care Surgery

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Fever and Hypotension in the Intensive Care Unit

Monica Lee, Areg Grigorian, Christian de Virgilio, and Joanne M. Bando

Case Study

A 57-year-old male patient develops confusion and lethargy in the intensive care unit. He is 4 days status post emergent surgery for a perforated gastric ulcer that developed as a result of daily nonsteroidal anti-inflammatory drug (NSAID) use for chronic lower back pain. He was treated with an exploratory laparotomy and an omental (Graham) patch closure of the ulcer. On physical examination, his temperature is 39.2 °C, heart rate is 96

beats per minute, respiratory rate of is 24/minute, and blood pressure is 82/62 mmHg. Oxygen saturation is 92% on room air. The surgical incisions appear clean and intact, and the abdomen is nontender. There are diminished breath sounds on the right. His urine output has been 10 cc/hour for the last 6 hours, and the urine appears dark. Laboratory values reveal a white blood cell count of $18 \times 10^3/\mu\text{L}$ (normal $4.1\text{--}10.9 \times 10^3/\mu\text{L}$),

serum creatinine of 3.2 mg/dL (from a baseline of 1.1 three days earlier), and a blood pH of 7.1. Chest x-ray demonstrates a large area of consolidation in the right lower lobe. Given his lethargy, tachypnea, and low oxygen saturation, he is intubated by way of rapid sequence intubation. He is given several IV fluid boluses; however, the blood pressure does not improve. A vasopressor is initiated. Blood cultures are sent.

Diagnosis

What Is the Differential Diagnosis for a Post-op Patient with Fever?

Table 1.1

Diagnosis	Comments
<i>Aspiration pneumonitis</i>	Symptoms may consist of cough, wheezing, and shortness of breath
<i>Atelectasis</i>	Partial or complete collapse of a lung, often bibasilar, from obstruction or extrathoracic restriction (including pain); causes shortness of breath and hypoxemia; debatable whether it actually causes fever (may be coincidental as opposed to causal)
<i>Drug reaction</i>	Usually a diagnosis of exclusion if no other symptoms are present; may have a rash
<i>Pneumonia</i>	Productive cough, dyspnea, chest pain, and respiratory distress
<i>Surgical site infection</i>	Tenderness, erythema, swelling, warmth, delayed healing, purulent discharge
<i>Urinary tract infection</i>	Minimize catheter use and duration (less than 2 days, if possible)
<i>Venous thromboembolism</i>	Includes deep vein thrombosis and pulmonary embolism; prevented with chemical prophylaxis, sequential compression, and ambulation
<i>Adrenal insufficiency</i>	Hypotensive despite fluid resuscitation and vasopressors; may have fever, hyponatremia, hyperkalemia, hypoglycemia

What Is the Classic Timing for the Different Causes of Postoperative Fever (the Five Ws)?

Table 1.2

W	Comment	Occurs
<i>Wind</i>	Atelectasis or pneumonia	POD 1
<i>Water</i>	Urinary tract infection	POD 3
<i>Walk</i>	Venous thromboembolism	POD 5
<i>Wound</i>	Infection	POD 7
<i>Wonder drugs</i>	Drug reaction	Anytime
POD postoperative day		

Watch Out

Necrotizing postoperative wound infections (due to *Clostridia* or *beta-hemolytic Streptococcus*) can rarely occur within 12 hours of surgery. Such infections need prompt broad spectrum IV antibiotics and return to the operating room for debridement.

What Is the Most Likely Diagnosis in This Patient?

The combination of fever and leukocytosis strongly suggests a diagnosis of sepsis, and given the diminished breath sounds and chest x-ray findings, the sepsis is most likely due to pneumonia. The addition of hypotension indicates that the patient is in shock. Although the differential of shock is broad (see below), with these findings, sepsis is the most likely cause.

In addition, a rising creatinine, decreased urine output, and mental status changes indicate that there is end-organ damage.

What Other Diagnoses Should Be Considered in a Postoperative Patient with Fever and Hypotension?

Pulmonary embolism can also cause fever and hypotension (although the chest x-ray will generally be negative). Rarely, acute adrenal insufficiency can develop postoperatively (most often in patients with a history of steroid use), with a classic combination of fever, hyponatremia, hyperkalemia, hypoglycemia, and hypotension that is refractory to fluids and pressors.

History and Physical

What Clues Are Expected on History and Physical for a Patient in Sepsis?

The history and physical examination should provide clinical clues so as to have a targeted approach to work up a septic patient. Always examine surgical wounds. Inspect the skin at the port of entry and all indwelling catheters (IV's, central lines) for evidence of infection. Look for other indwelling catheters (such as a bladder catheter) that might be a source of sepsis. If the patient progresses to shock, inflammatory mediators can lead to organ damage, which can present as oliguria, increased BUN and creatinine, and mental status changes. The skin is often warm and flushed from the increased peripheral vasodilation as total systemic vascular resistance drops similar to neurogenic shock, whereas other types of shock lead to cold, clammy skin. Confusion, disorientation, agitation, and anxiety are common in septic patients (septic encephalopathy). While fever is a common presentation for infection, an afebrile patient does not exclude sepsis. Patient populations who may not present with fevers include the very young, the elderly, those with dialysis-dependent renal failure, and the immunocompromised.

What Is the Sequential Organ Failure Assessment (SOFA) and Quick SOFA (qSOFA) Score?

In 2016, the *Third International Consensus Definitions for Sepsis and Septic Shock* redefined the current definition used for sepsis and septic shock. The previously used definition of sepsis (2+ Systemic Inflammatory Response Syndrome criteria and a source of infection) was thought to be too nonspecific and generally unhelpful in the identification of patients at increased risk of mortality from infection. Sepsis is currently defined as life-threatening organ dysfunction caused by a dysregulated

host response to infection. A bedside screening tool called the qSOFA identifies patients likely to have a poor outcome as the result of an infection. A patient who meets two of the three criteria (respiratory rate $\geq 22/\text{min}$, altered mental status, and systolic blood pressure $\leq 100 \text{ mmHg}$) (such as the patient presented) has a higher risk for sepsis-related mortality.

The more detailed SOFA score takes objective criteria from multiple organ systems and assigns a score based on the amount of organ dysfunction. The score includes $\text{PaO}_2/\text{FiO}_2$ ratio, platelet count, Glasgow Coma Scale (GCS), bilirubin, blood pressure, and creatinine.

Finally, the term septic shock has been redefined as sepsis that, despite adequate fluid resuscitation, requires vasopressors to keep the mean arterial pressure (MAP) $\geq 65 \text{ mmHg}$ and have a lactate $> 2.0 \text{ mmol/L}$. The term “severe sepsis” is no longer being encouraged as a formal diagnosis.

What Physical Exam Findings Suggest that a Patient Is Unable to Protect Their Airway?

A patient who is obtunded, has a GCS score of 8 or less, has an absent gag reflex, or has an inability to swallow is unable to protect his or her airway.

Watch Out

If the GCS is less than 8, intubate.

Pathophysiology

What Are the Different Types of Shock?

Table 1.3

Type of shock	Causes	Pre-load	Cardiac output	After-load
Cardiogenic	MI, cardiac injury, arrhythmias, myocarditis	↑	↓	↑
Distributive (septic)	Anaphylaxis, sepsis, neurogenic shock	↓	↑	↓
Hypovolemic	Hemorrhage, dehydration, burns	↓	↓	↑
Obstructive	Cardiac tamponade, tension pneumothorax, pulmonary embolism	↑	↓	↓

1 What Is the Pathophysiology of Septic Shock?

Sepsis is an inflammatory cascade that attempts to control a noxious stimulus (such as bacterial invasion). The core problem of septic shock is not poor perfusion but the poor *utilization* of oxygen. Therefore, hypotension is a sequelae and marker of the inflammation, and not a contributing factor to the pathophysiology of sepsis. Inflammatory mediators chiefly impair mitochondrial oxidation by inhibiting pyruvate dehydrogenase and cytochrome oxidase, and thus destroy the cell's ability to produce adenosine triphosphate. Additionally, inflammatory mediators induce production of nitrous oxide resulting in systemic vascular dilation and high cardiac output (from increased heart rate). As stroke volume continues to decrease and stress on the cardiovascular system increases in untreated sepsis, compensatory tachycardia is unable to maintain cardiac output. The systemic venodilation sequesters the majority of the intravascular volume in the venous system, which is the basis of why fluid resuscitation is essential early in septic shock. However, to avoid the mortality associated with a large positive fluid balance, fluids should be titrated to an adequate urine output. Lastly, although there is systemic vascular dilation, there is relative splanchnic vasoconstriction resulting in gut ischemia and mucosal injury. This allows for enteric pathogen translocation and additional subsequent inflammation; this self-sustaining process of continued inflammation is known as the “motor” of multi-organ failure.

What Is Acute Respiratory Distress Syndrome (ARDS)?

ARDS is an acute, diffuse inflammatory lung injury that was redefined in 2012 under the Berlin definition into a three-tiered grading system consisting of mild, moderate, and severe ARDS. Patients with ARDS have acute onset of respiratory symptoms and bilateral radiographic opacities not fully explained by heart failure. Trauma, sepsis, infection, or an inflammatory trigger leads to the release of pro-inflammatory cytokines which recruit and activate neutrophils, which cause diffuse alveolar epithelial and endothelial damage. The resulting vascular leakage leads to diffuse pulmonary edema with fibrin secretion, hyaline membrane formation, loss of aerated lung tissue, and remodeling. There is resulting hypoxemia, increased physiological dead space, and decreased lung compliance.

If the Patient Were to Become Pulseless, What Are the Hs and Ts to Consider?

Table 1.4

H	Hypovolemia, hypoxia, hydrogen ion (acidosis), hypokalemia, hyperkalemia, hypothermia
T	Toxins (cocaine, tricyclics, digitoxin, beta blockers, calcium channel blockers), tamponade, tension pneumothorax, thrombosis (MI or PE)

Workup

What Are the Initial Laboratory Studies to Order for a Patient in Septic Shock?

Order a complete blood count with differential, comprehensive metabolic panel, coagulation studies, serum lactate, arterial blood gas (ABG), peripheral blood cultures, and a urinalysis. If the patient has an indwelling central venous catheter, obtain a culture from that site as well. The peripheral blood should be cultured for aerobes and anaerobes from at least two different sites.

What Is the Significance of Increased Serum Creatinine and Oliguria?

A patient with increased serum creatinine and oliguria has impaired kidney function and is at risk for acute kidney injury. The resulting metabolic acidosis may lead to worsening hypotension. Indications for acute renal replacement therapy are acidosis, hyperkalemia, uremia, and fluid overload. Such renal replacement should be considered early on in patients with septic shock and acute kidney injury.

What Is the Difference Between the Two Types of Renal Replacement Therapy: Hemodialysis (HD) and Continuous Renal Replacement Therapy (CRRT)?

CRRT and HD both provide fluid or solute removal through diffusion (dialysis), convection (filtration), or a combination of both. CRRT can be used as a continuous therapy, while

HD occurs over 3–6 hours 2–3×/week. The hourly rates of fluid and solute removal with CRRT are lower per hour than with intermittent HD and may be better tolerated by hypotensive patients. Because CRRT is continuous, this can allow for larger net solute and fluid removal over time. For the above patient in septic shock with acute kidney injury, the preferred option is CRRT.

What Are the Initial Imaging Studies to Order for a Postoperative Patient Believed to Be in Septic Shock?

Pneumonia should be suspected in patients with productive cough, respiratory distress, and prolonged ICU stay, and a chest x-ray should be ordered, as well as sputum cultures. Obtain abdominal plain films if there is suspicion for a bowel obstruction or perforation (keep in mind that a small amount of free air may persist for a few days after laparotomy). If there is clinical suspicion for an intra-abdominal source of infection, obtain a CT scan of the abdomen and pelvis (bearing in mind that intravenous contrast should be avoided with acute kidney injury). Ultrasound can be used to detect acute cholecystitis.

Watch Out

Intermittent bacteremia is common, so the blood culture may be negative. Continuous bacteremia is usually seen in a persistent endovascular infection such as endocarditis or those with an infected ventral venous catheter.

Management

What Are the Initial Management Goals for a Patient in Septic Shock?

The essential management of the septic patient includes early recognition, fluid resuscitation, blood cultures, broad-spectrum IV antibiotics, and vasopressors (norepinephrine first; then vasopressin). There is a notable absence of large randomized, controlled trials demonstrating improved survival of adjunctive treatment options aside from the above essentials. Urine output can be a surrogate for targeted fluid resuscitation with a goal of 0.5–1.0 mL/kg/h for adults. Blood products are only indicated if hemoglobin is <7.0 g/dL or if the patient is actively bleeding.

Send cultures from the suspected source of infection before starting antibiotics if it will not delay treatment. If the source is not known, obtain aerobic and anaerobic blood

cultures from two venipuncture sites. Start broad-spectrum IV antibiotics, and consider adding antifungal coverage if the patient is immunocompromised.

What Is Rapid Sequence Intubation (RSI)?

RSI is used to rapidly secure tracheal intubation in patients who have not fasted and as such are at high risk of vomiting and aspiration. The patient is medicated with weight based, full dose (rather than titrated) sedative and neuromuscular agents to allow intubation within several minutes. The patient should be pre-oxygenated for a minimum of 3 min prior to the administration of an induction agent (such as ketamine or etomidate) without bag-valve-mask ventilation. This is followed immediately by a neuromuscular blocking agent (such as rocuronium or succinylcholine).

Watch Out

Etomidate can rarely lead to Addisonian crisis within 24 hours after administration and result in persistent hypotension and fever.

Watch Out

Succinylcholine is a depolarizing agent that may lead to life-threatening hyperkalemia and should not be used acutely in patients with crush injury, burns, multiple trauma, or baseline hyperkalemia.

What Drugs Are Ideal to Use for Sedation in a Critically Ill and Intubated Patient?

Propofol (gamma-aminobutyric acid antagonist) is commonly used for sedation because it has a rapid onset and is short acting (effects continue for only 5–8 min). It is also useful in patients with head injury because it reduces intracranial pressure. Dexmedetomidine (alpha-2 agonist) is also commonly used as it allows for cooperative sedation and has a mild analgesic effect. It has also been demonstrated to reduce ICU delirium. Both propofol and dexmedetomidine can have potential side effects of hypotension and bradycardia. Benzodiazepines can also be used for sedation but have largely been replaced because they seep into adipose tissue, which can lead to prolonged effect even after discontinuation of the drug and make weaning from the ventilator difficult. Propofol and benzodiazepines have no analgesic effect.

What Drugs Are Ideal to Use for Analgesia in a Critically Ill and Intubated Patient?

Opioids are the most widely used medications for analgesia in the hospital. Of the available opioid drugs, fentanyl is the most commonly used in critically ill patients because it has a fast onset (highly lipid soluble) and low risk of hypotension (not associated with histamine release) and does not have highly active metabolites (does not need to be renally dosed). Two non-opioid analgesics commonly used in the ICU are acetaminophen and NSAIDs (ketorolac, ibuprofen.) These drugs can help decrease the amount of opioid use.

How Should the Patient's Oliguria Be Managed?

Oliguria in the presence of adequate fluid resuscitation indicates acute kidney injury (AKI). Patients in the ICU with AKI and septic shock may require renal replacement therapy. The slower rate of fluid and solute clearance per unit time of CRRT compared to intermittent HD may be better tolerated in patients with septic shock and hemodynamic instability.

What Is the Significance of a Low pH?

As tissue oxygenation decreases, anaerobic energy production increases and creates lactic acid as a byproduct. The acidosis activates potassium channel pumps and nitric oxide synthases to hyperpolarize and vasodilate vascular smooth muscle cells. The local effect of low pH coupled with the vasodilatory effects of inflammatory mediators perpetuates the hypotension in sepsis.

How Are Glucose Levels Managed in the Septic Patient?

Due to the high metabolic demand of a septic patient, insulin regimens are initiated when two consecutive blood glucose levels are >180 mg/dL. Intensive glycemic control is no longer favored as this has been shown to cause more morbidity than maintaining more moderate glycemic control (see NICE-SUGAR trial).

If the Patient Became Pulseless, How Should ACLS Be Executed?

For any emergency patient, assess the ABCs: airway, breathing, and circulation. Scan for breathing while firmly tapping and asking the patient to speak to check their airway. If there is no palpable carotid pulse, begin chest compressions immediately at a rate of 100 compressions/minute.

Attach the monitor and defibrillator to the patient, and continue chest compressions for 2 min. Then, check for a pulse and determine if the rhythm is shockable (pulseless ventricular tachycardia and ventricular fibrillation). If it is, shock the patient and resume chest compressions. After 2 min, recheck the pulse and rhythm and shock again if warranted. If the patient does not respond after this second cycle of chest compressions and defibrillation, give 1.0 mg epinephrine. Continue to recheck pulse and rhythm, shock if warranted, and give epinephrine every 3–5 min. If the patient continues to remain in ventricular tachycardia or ventricular fibrillation, amiodarone may replace epinephrine only for the second dose.

If the rhythm is not shockable (pulseless electrical activity or asystole), resume chest compressions for 2 min, and administer 1.0 mg epinephrine. Continue CPR and epinephrine boluses every 3–5 min until the underlying cause is treated or the rhythm becomes shockable.

What Is the Difference Between Synchronized and Desynchronized Shock?

Synchronized shock (cardioversion) is the delivery of a low-energy shock which synchronizes to the QRS complex. There is a delay after the shock button is pressed to allow synchronization to the heart's natural electrical beat to avoid shocking during the T wave, which can initiate ventricular fibrillation. It is used for unstable atrial fibrillation, atrial flutter, and supraventricular tachycardias unresponsive to medication.

Desynchronized shock (defibrillation) is the delivery of a random high-energy shock as soon as the shock button is pressed irrespective of the QRS complex. It is used when there is uncoordinated intrinsic electrical activity in the heart, such as pulseless ventricular tachycardia or ventricular fibrillation.

Summary of Essentials

History and Physical

- Sepsis is defined as life-threatening organ dysfunction caused by a dysregulated host response to infection.
- A qSOFA score ≥ 2 identifies patients likely to have a poor outcome as the result of an infection.
- Signs of infection: fever, warm and flushed skin, and leukocytosis
 - Check for end-organ damage as evidenced by increased creatinine, decreased urine output, decreased platelet level, elevated bilirubin, increased oxygen requirements, and mental status changes.
 - Shock: Vasopressors needed despite adequate fluids and a lactate >2.0 mmol/L.

Pathophysiology

- Septic shock is systemic inflammation characterized by poor utilization of oxygen
- Inflammatory mediators inhibit the body's ability to produce energy and cause vasodilation
 - Cardiac output initially increases with the increased heart rate but is eventually compromised as venodilation pools venous return.

Workup

- CBC, CMP, coagulation studies, lactate, ABG, blood cultures, and urinalysis
- Check for sources of infection based on patient's presentation and history

Management

- IVF, broad-spectrum antibiotics, and vasopressors if needed
 - Tailor the antibiotics based on cultures and sensitivities
- ABCs: check airway, breathing, and circulation
 - Intubate if GCS <8
 - Achieve rapid sequence intubation with an induction agent (such as etomidate) and a paralytic (such as succinylcholine)

- Use propofol or dexmedetomidine for sedation in a critically ill and intubated patient
- Pulseless patient: start CPR
 - Ventricular tachycardia or ventricular fibrillation: shock ->. If patient remains unresponsive after two cycles of defibrillations, continue CPR with epinephrine.
 - Pulseless electrical activity or asystole: CPR with epinephrine and correct underlying cause (Hs and Ts)
- If renal replacement therapy is indicated for AKI, start CRRT in ICU patients who are hemodynamically unstable and requiring vasopressors despite adequate fluid resuscitation.
- Target blood sugars above 180 mg/dL

Suggested Reading

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Nausea, Vomiting, and Left Groin Mass

Areg Grigorian, Christian de Virgilio, and David C. Chen

Case Study

A 65-year-old obese woman presents to the emergency department with nausea and vomiting for the past day. The frequency of vomiting has increased despite the fact that she has not eaten for the past 12-h. Over the last few months, she has noticed a painful “lump” in her left groin that protrudes upon straining (i.e., coughing, bowel movements) but quickly disappears after lying down. She reports that the lump

reappeared a few days ago but she can no longer push it back in. She has had no bowel movement and no flatus per rectum for the past 24-h. Her temperature is 37.9 °C, blood pressure 120/80 mmHg, and heart rate 120/min. She appears ill and uncomfortable with dry mucous membranes. Lung sounds are clear bilaterally. Her abdomen is mildly distended. Bowel sounds are high pitched with tinkles and

rushes. Her abdomen is non-tender to palpation. There is a 2 × 2 cm mass in the left groin inferior to the inguinal ligament that is very painful to palpation. The overlying skin is slightly erythematous. The bulge is just medial to her femoral pulse, extending toward her thigh compartment. Laboratory studies are significant for white blood count of $14.7 \times 10^3/\mu\text{L}$ (normal $4.1\text{--}10.9 \times 10^3/\mu\text{L}$).

Diagnosis

What Is the Differential Diagnosis for a Groin Mass (Use *MINT* Mnemonic)?

Table 2.1

Type	Examples	Comments
Malformation	Undescended testicle, varicocele, hydrocele, hernias	Hernias will protrude with straining and may reduce with pressure
Infectious/inflammatory	Lymphadenopathy (reactive), mononucleosis (EBV), abscess, sarcoidosis, lymphogranuloma venereum	“Shotty,” tender lymph nodes are typically reactive from local minor infections, scrapes, or cuts
Neoplastic	Lymphoma, lipoma, lymphadenopathy, metastatic cancer (anal, skin, genital)	Large non-tender lymph nodes limited to the inguinal region suggest metastatic cancer (melanoma, anal, or genital cancer) (testicular cancer does not usually metastasize to the groin; it more commonly travels to the retroperitoneum)
Traumatic	Hematoma, femoral aneurysm, or pseudoaneurysm	Inquire about a history of recent trauma or intervention

EBV Epstein-Barr virus

What Is the Diagnosis for This Patient?

The diagnosis for this patient is small bowel obstruction (SBO) secondary to a strangulated hernia. The presence of abdominal distention, a groin mass (below the inguinal ligament), and high-pitched bowel sounds in a patient with progressive nausea with vomiting is highly suggestive of acute intestinal obstruction from a femoral hernia. The addition of systemic signs of inflammation or infection (fever, tachycardia, leukocytosis) and localized pain and redness of the skin overlying the hernia strongly suggests that the bowel within the hernia sac is ischemic or gangrenous. In this setting, emergent surgical intervention is necessary.

History and Physical

Why Is It Important to Examine for Inguinal Lymphadenopathy?

Most often, a mass in the inguinal region in men and women will represent enlarged lymph nodes. Lymph nodes may enlarge either due to autoimmune disease, malignancy, or as a response to a localized or systemic infection. It is relatively common for adults to have small “shotty” (resembling lead pellets) lymph nodes in the inguinal region representing “reactive” lymphadenopathy with follicular hyperplasia in response to minor infections, cuts, or scrapes in the groin, perineum,

or lower extremity. Reactive nodes are usually sub-centimeter, mobile, tender, and firm. If nodes are very large, tender, and limited to the inguinal region, one must consider syphilis, chancroid, and lymphogranuloma venereum. Large non-tender inguinal lymphadenopathy limited to the inguinal region suggests metastatic cancer from a local source (melanoma, anal, or genital cancer). Large non-tender inguinal lymph nodes associated with diffuse lymphadenopathy suggest a systemic process (infectious, malignant, or autoimmune) such as tuberculosis, lymphoma, leukemia, HIV, or sarcoidosis.

Why Is It Important to Ask if a Groin Mass Protrudes with Straining?

A groin mass that protrudes with straining (Valsalva) and reduces in the supine position is highly suggestive of a hernia. Acquired hernias develop as a result of structural weakness of the abdominal wall in conjunction with increased intra-abdominal pressure. Contributing factors include prior incisions, heredity, constipation, multiple pregnancies, obesity, and liver disease with ascites. History should include conditions that lead to chronic straining, as these may provide clues to underlying untreated conditions such as a chronic cough (chronic bronchitis, lung cancer), constipation (colon cancer), or urinary straining (benign prostatic hypertrophy, prostate cancer). It is also important to inquire about work- and activity-related issues such as heavy lifting and physical exertion.

Pathophysiology

What Is a Hernia?

A hernia is a protrusion of tissue or organ(s) through a defect, most commonly in the abdominal wall. In abdominal hernias, peritoneal contents, such as the omentum and/or bowel, may protrude through a defect or weakness in the muscle/fascia. Hernias have three components: the abdominal wall defect, the hernia sac which protrudes through the defect, and the contents within the sac. The neck of a hernia is the part of the hernia sac adjacent to the abdominal wall defect. If the neck is narrow (as is the case for most femoral hernias), the bowel herniates less frequently, but once it does enter, it has a higher chance of becoming constricted by the narrow neck and becoming incarcerated.

What Is the Difference Between a Reducible and an Incarcerated Hernia? Between an Incarcerated and a Strangulated One?

A hernia can be described as *reducible* if the contents within the sac can be pushed back through the defect into the peritoneal cavity, whereas with an *incarcerated* hernia, the contents are stuck in the hernia sac. A *strangulated* hernia is a type of

incarcerated hernia in which there is compromised blood flow to the herniated organ (usually the small intestine but can also be the omentum, large bowel, or ovary). Strangulation more frequently occurs when the hernia defect is narrow. A loop of bowel protrudes through the hernia and becomes entrapped by the narrow neck. This may lead to a closed-loop bowel obstruction with both ends of the bowel blocked and nowhere for fluid and gas to egress. As the bowel continues to produce gas and secrete fluid, the progressive distention leads to a compromise of the blood flow. A strangulated hernia requires prompt surgical intervention as delays lead to worsening sepsis and death. The overall incidence of strangulation in inguinal hernias is much less than 1%. This risk, however, is increased in symptomatic patients and those with significant comorbidities. Predisposing risk factors include older age, duration of hernia (shorter is worse), type (femoral), and comorbidities. Some hernias (particularly those with large defects) can be chronically incarcerated (and therefore irreducible) for years without causing major symptoms (e.g., a large scrotal or large incisional hernia). Others (particularly with narrow necks) are at higher risk of progressing to strangulation.

What Is the Pathophysiology of an Indirect Inguinal Hernia? A Direct Inguinal Hernia?

In general, indirect inguinal hernias are congenital, whereas direct hernias are acquired. *Indirect inguinal hernias* are caused by a persistent (patent) processus vaginalis. During embryologic development, the processus vaginalis, an out-pouching of the peritoneum, descends into the scrotum, bringing along the testicle with it. It subsequently closes prior to birth. If the processus remains patent (open), peritoneal fluid can fill the scrotum (communicating hydrocele), or the bowel can pass through the patent processus vaginalis into the scrotum (indirect hernia). In men, the indirect hernia sac travels along with the spermatic cord through the internal ring and into the scrotum. In women, it follows the tract of the round ligament toward the pubic tubercle. *Direct inguinal hernias* are due to a weakness in the floor (transversalis fascia) of the inguinal canal, directly through Hesselbach's triangle medial to the inferior epigastric vessels. They typically manifest after years of chronic straining, causing wear and tear to the abdominal wall musculature. Since they are acquired, it is unusual to find a direct inguinal hernia in a young person. The neck of an indirect inguinal hernia is relatively narrow as it passes through a relatively rigid and inflexible space (the internal ring), whereas direct inguinal hernias typically have a more broad-based neck, making strangulation less likely to occur.

Watch Out

Indirect inguinal hernias traverse the deep ring and the superficial ring, while direct inguinal hernias *only* pass through the superficial ring.

What Are the Borders of Hesselbach's Triangle?

The lateral border is formed by the inferior epigastric vessels, the medial border by the rectus sheath, and the base by the posterior wall of the inguinal ligament.

What Are the Other Types of Hernias?

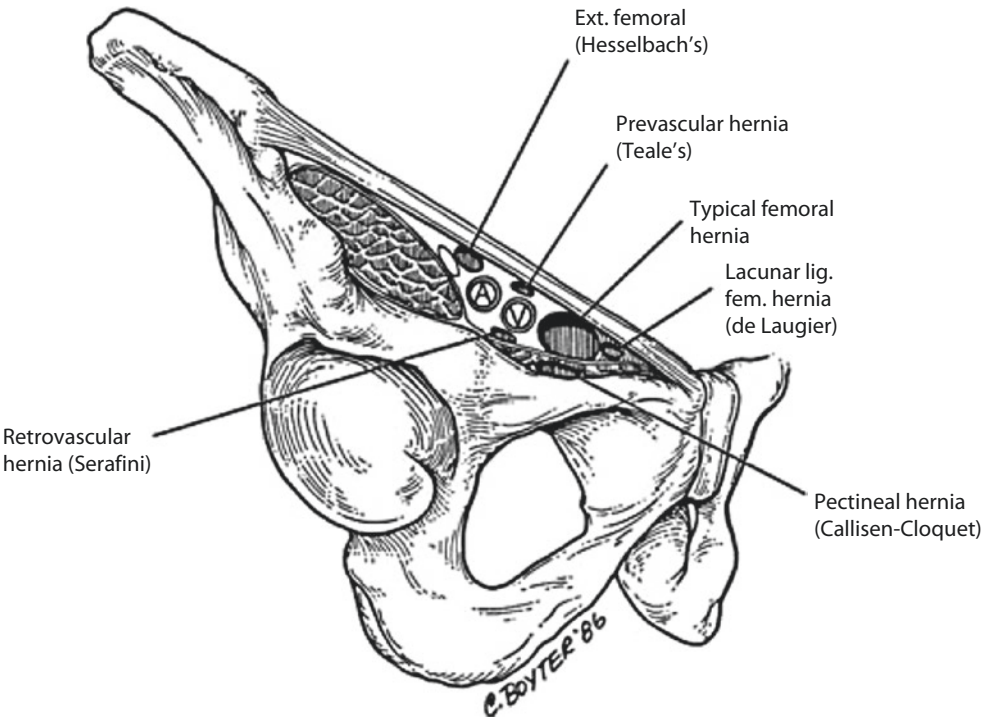
Femoral hernias occur in the femoral canal (■ Fig. 2.1), inferior to the inguinal ligament traversing the empty space medial to the femoral vein. Although they appear infrequently in patients (10% of all hernias), they are much more common in women (particularly multiparous women) and have the *highest* rate of strangulation (■ Table 2.2). *Umbilical hernias*

(■ Fig. 2.2) are prevalent in the pediatric population and common with congenital hypothyroidism. In children, most are asymptomatic and close spontaneously with no intervention (surgery if persists beyond age 4). In adults, umbilical hernias are associated with increased intra-abdominal pressure (pregnancy, ascites, weight gain). Surgery is recommended if symptomatic. *Ventral or incisional hernias* appear most commonly in the midline or at the site of a previous surgical incision and can occur weeks, months, or even years after the procedure.

Watch Out

Recall the mnemonic “NAVEL” for a femoral hernia; from lateral to medial: femoral nerve, artery, vein, empty space (hernia protrudes), and lymphatic.

■ Fig. 2.1 Femoral hernia.
(From: Ates M, et al. First laparoscopic totally extraperitoneal repair of Laugier's hernia: a case report. *Hernia*. 2013;17(1):121–3. Reprinted with permission from Springer Nature)



■ Table 2.2 Inguinal hernia

Type	Anatomy	Pathophysiology	Hernia sac lining	Other
Direct inguinal hernia	Protrudes through the abdominal wall (Hesselbach's triangle), medial to the inferior epigastric artery	Acquired weakness in the abdominal floor, chronic straining	Peritoneum	Least likely to incarcerate, more common in men
Indirect inguinal hernia	Protrudes through the internal inguinal ring lateral to the inferior epigastric artery	Congenital	Patent processus vaginalis, peritoneum	The most common hernia in men, women, and children
Femoral hernia	Passes through the femoral canal, into empty space medial to femoral vein	Multiple pregnancies increase risk for hernia though narrow femoral neck	Peritoneum	More common in women, most likely to incarcerate/strangulate



Fig. 2.2 Umbilical hernia. (From Miller R, et al. Umbilical hernia in babies and children. In: LeBlanc K, Kingsnorth A, Sanders D, editors. *Management of abdominal hernias*. Cham: Springer; 2018. Reprinted with permission from Springer Nature)

Why Are Femoral Hernias More Prone to Incarceration?

Bowel entering a femoral hernia passes down the narrow femoral canal. The femoral ring, which serves as the entrance to the femoral canal, is very rigid and unyielding. Thus, the fixed neck of a femoral hernia is prone to pinching off the bowel, putting the patient at risk for incarceration.

What Is the Significance of a Suspected Hernia Being Below as Opposed to Above the Inguinal Ligament?

A hernia below the inguinal ligament indicates that it is a femoral hernia, which passes under (posterior to) the inguinal ligament.

What Is a Richter's Hernia?

It is a type of hernia that occurs when only *part of the circumference* of the bowel wall is trapped within the hernia sac. The herniated segment can become strangulated and result in ischemia/gangrene. Since only part of the wall of the small intestine is herniated, patients do not have signs or symptoms suggestive of bowel obstruction. The absence of obstruction may mislead the clinician into thinking that the bowel is not at risk for strangulation.

What Is a Sliding Hernia?

A sliding hernia is a type of indirect hernia that occurs when a retroperitoneal organ (usually colon or bladder) typically herniates with the sac and essentially makes up the posterior wall of the sac. It usually occurs in males and more often on the left side. A sliding hernia should be suspected when the posterior

wall of the hernia sac feels thickened. It is particularly dangerous because if it is not recognized, the bowel can easily be injured or transected when dividing the hernia sac. An indirect hernia sac should always be opened anteriorly as this will prevent making a hole in the bowel or bladder if a sliding hernia is present.

Watch Out

A hernia containing the appendix is termed Amyand hernia, while one containing small bowel with a Meckel diverticulum is termed Littre hernia. Remember, Amyand for appendix and Littre for little kids (Meckel).

Workup

How Do You Diagnose a Hernia in an Adult?

Hernias are considered a clinical diagnosis. A good history (of a reducible mass that protrudes with straining) and a good physical exam are typically all that is needed. For both men and women, the patient is asked to stand. In men, the examiner's index finger is inserted in a cephalad direction through the scrotum, inverting it, and placed at the level of the external ring. The patient is asked to Valsalva or cough. If a hernia is present, a bulge will be palpated.

How Do You Diagnose a Hernia in an Infant?

Both indirect inguinal hernias and umbilical hernias are common in infants. The physical exam may be challenging as the infant cannot cough or strain on command. Thus, the history from the parent of a noticeable bulge with crying is important. Raising the infant's arms will make the infant struggle, increasing intra-abdominal pressure, often permitting visualization of the hernia bulge.

How Do You Distinguish Between a Direct and an Indirect Inguinal Hernia Intraoperatively?

Indirect inguinal hernias originate lateral to the inferior epigastric vessels, while direct inguinal hernias pass medial within Hesselbach's triangle. Indirect inguinal hernias travel through the internal ring along with the spermatic cord.

What Is the Role of Imaging Studies in the Diagnosis of Hernia?

Abdominal hernias are typically diagnosed on the basis of a history and physical exam. However, at times, physical exam will be nondiagnostic despite a history that is strongly suggestive of a hernia. In particular, hernias may be difficult to appreciate in the morbidly obese, due to abundant subcutaneous fat. In these circumstances, adjunctive imaging studies may

aid in the diagnosis. Ultrasound with Valsalva is cost-effective and will often demonstrate an inguinal hernia but has limited efficacy in the obese patient. Cross-sectional imaging including computed tomography (CT) scan or magnetic resonance imaging (MRI) may be helpful. CT scan and MRI are also useful for rare abdominal wall hernias (such as Spigelian hernias) as they lie in between two layers of the abdominal wall, making these difficult if not impossible to palpate. CT is more cost-effective and convenient than MRI, but both provide similar information. In addition, a CT scan is an important diagnostic tool in the setting of a bowel obstruction, as it may demonstrate an undiagnosed hernia as the cause (■ Figs. 2.3 and 2.4).

Management

What Is the Principle Component of the Operative Management of an Indirect Inguinal Hernia in an Adult? How About a Direct Inguinal Hernia?

For an indirect hernia, the main goal is to open the sac (anteriorly), assess viability of the intestine, reduce any contents, and then perform a high ligation (at the internal

ring) of the hernia sac. This eliminates the patent processus vaginalis. This is all that needs to be done in pediatric cases. The distal sac can be excised if small or left in situ if large. In addition, in adults, the long-standing protrusion of the hernia through the internal ring weakens the surrounding muscle. As such, the floor of inguinal canal is reinforced with a tension-free mesh repair (Lichtenstein repair). With a direct hernia, since there is no patent processus vaginalis, the sac is not opened nor ligated. Since the sac consists of peritoneum and protrudes through the weakened floor of the inguinal canal, the sac is just reduced, and the floor of the inguinal canal is reinforced similarly to indirect hernias with a Lichtenstein repair. An alternative to using mesh is to close the hernia defect and strengthen the floor by sewing the elements of the floor together as a tissue-based repair (Bassini, Shouldice, McVay). Such repairs (without mesh) have the disadvantage of being under tension, and as such the hernia recurrence rates are significantly higher. These repairs are typically reserved for situations where mesh is unavailable, contraindicated (infection, gangrenous bowel), or declined (pain, preference, sensitivity). Laparoscopic inguinal hernia repair may be used to repair indirect, direct, and femoral hernias utilizing a posterior approach to the myopectineal orifice with mesh reinforcement.

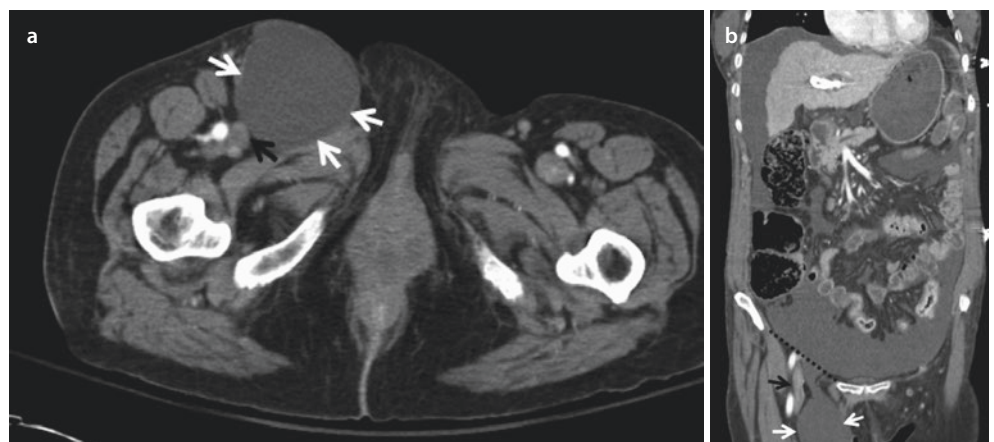


■ Fig. 2.3 Normal pelvic CT without hernia. White arrows: normal inguinal canals

What Are the Principles of the Management of an Incarcerated Hernia?

Acutely incarcerated hernias are at risk of progressing to strangulation and require prompt attention. Provided there is no evidence of strangulation already, an attempt should be made to reduce the incarcerated hernia. This is typically done by placing the patient in slight Trendelenburg position, providing some sedation and analgesia, applying a cold compress, and then attempting gentle manual compression. The advantage of reduction is that it converts an emergent procedure into a semi-elective one and makes the operation easier as there will be less inflammation. If the hernia is not reducible, urgent surgical intervention is required.

■ Fig. 2.4 Axial **a** and coronal **b** CT scans showing a right-sided femoral hernia. Note that it is medial to the femoral vein and inferior to the inguinal ligament. White arrows: hernia sac. Black arrows: femoral vein. Black dotted line: location of inguinal ligament



What Is the Recommendation for Inguinal Hernia Repair in Older Infants/Children?

The vast majority of hernias in infants are indirect hernias. Thus, high ligation of the hernia sac alone adequately corrects this defect. Since pediatric hernias typically have a smaller internal ring relative to its final adult size, the internal ring and the floor of the inguinal canal do not need reinforcement.

What Is the Recommended Management for an Umbilical Hernia in an Infant?

Umbilical hernias are very common in newborns. They rarely incarcerate and most close spontaneously by age 2. Indications for surgery are persistence beyond age 4, hernia defect larger than 2 cm in diameter (unlikely to close spontaneously), strangulation, or progressive enlargement after 1–2 years of age.

Complications

What Nerves Can Be Injured During Hernia Repair? What Is the Mechanism of Injury? What Are the Consequences?

Table 2.3

Injury	Deficit
Genital branch of the genitofemoral nerve	Loss of cremaster reflex and pain or loss of sensation in the anterior scrotum/labia majora (genital branch)
Ilioinguinal nerve	Pain or loss of sensation at the base of the penis, mons pubis, and inner thigh
Iliohypogastric nerve	Pain or loss of sensation in the suprapubic region
Lateral femoral cutaneous nerve (meralgia paresthetica)	Pain or loss of sensation in the lateral side of the thigh, commonly extending to the knee, more common during laparoscopic repair

Watch Out

The most common nerve injured during open hernia repair is the *ilioinguinal nerve*. The most common nerve injured during laparoscopic repair is the *lateral femoral cutaneous nerve*.

Areas Where You Can Get in Trouble

Attempting to Reduce a Strangulated Hernia

Strangulated hernias imply that the bowel is compromised. Although the goal is to quickly restore blood flow to avoid bowel necrosis, this is not always possible, and the bowel may already be gangrenous upon presentation. If reduced, the gangrenous bowel will be pushed back into the peritoneal cavity, leading to sepsis and peritonitis. The only safe approach to reducing a strangulated hernia is in the operating room after confirming the bowel is not dead.

Dissecting and Excising the Distal End of a Large Indirect Hernia Sac

The primary goal of indirect hernia repair is division of the hernia sac with proximal ligation near the internal ring. The distal sac, if small, is typically excised. However, if the indirect hernia sac is large, it will extend into and be adherent to the scrotum. In this situation the distal hernia sac may be left in situ. Attempting to remove the entire sac requires extensive dissection and carries an increased risk of disrupting the venous drainage of the testicle which is the leading cause of testicular ischemia.

Chronically Reducible Hernia with SBO

Some patients may have a reducible hernia for years, and as long as it does not cause pain, episodes of obstruction, or decreased quality of life, they may elect to continue with watchful waiting. However, repeatedly reducing the hernia sac can lead to fibrosis of the hernia sac and surrounding tissue increasing increase risk for “reduction *en masse* of inguinal hernia.” In this condition, the hernia sac is reduced into the preperitoneal space, but the bowel is still strangulated within the fibrosed, trabeculated hernia sac leading to bowel obstruction and ischemia *without* an incarcerated or strangulated hernia appreciated on exam. CT scan can help demonstrate bowel obstruction in the preperitoneal hernia sac.

Areas of Controversy

Do You Repair or Observe Asymptomatic Inguinal Hernias?

There is ongoing debate as to whether asymptomatic inguinal (direct and indirect) hernias in adults should be repaired or whether one should wait for symptoms to develop. A large

prospective randomized controlled trial supports the premise of “watchful waiting,” provided no symptoms develop. More recent studies confirm the safety of watchful waiting but suggest that the majority of asymptomatic patients eventually do become symptomatic. Most surgeons will offer elective repair of asymptomatic inguinal hernias. Since femoral hernias are at higher risk of incarceration, repair is routinely recommended.

What Is the Recommended Management for an Inguinal Hernia in a Premature Infant?

Premature infants are at higher risk of incarceration, with bowel necrosis and gonadal ischemia. However, premature infants are also at much higher risk of complications from surgery (pulmonary from general anesthesia, injury to the vas deferens due to small size). Data regarding optimal timing of repair are conflicting. Most pediatric surgeons agree that optimal management is to delay surgery until infant is out of the ICU.

Do You Repair Asymptomatic Ventral/Incisional Hernias? Is Mesh Needed for Repair?

Incisional hernias typically develop after prior abdominal surgery. De novo ventral hernias will typically arise in the midline linea alba. Most surgeons will offer watchful waiting for asymptomatic incisional/ventral hernias. Incisional hernia repairs, due to the fact that they are re-operative, have more risk, as adhesions may be encountered with potential bowel injury during surgery. Depending upon the size of the hernia defect, mesh is generally used for repair. Mesh decreases the chances of hernia recurrence compared to sutures alone. However, there are several potential mesh-related complications that arise including mesh infection, recurrence, adhesions, pain, and erosion into the bowel with fistula formation. Preferred techniques involve placing the mesh in an extra-peritoneal position, to avoid contact with the bowel.

Do You Repair Inguinal Hernias Laparoscopically or Open?

Laparoscopic inguinal hernia repair has a slightly higher recurrence rate than open. However, most recurrences occur early in the learning curve for an individual surgeon, whereas outcomes are excellent with experienced laparoscopic surgeons. Conversely, open repair is associated with slightly more postoperative pain. Both are considered acceptable alternatives with similar results. Current recommendations define a clear benefit for laparoscopic hernia repair in cases of bilateral inguinal hernias (less pain) and for recurrent inguinal hernias after prior open repair (less pain, similar results). Primary unilateral hernias may be repaired by either method.

Summary of Essentials

History and Physical

- Must differentiate between inguinal and scrotal masses
- With hernias, look for factors that increase intra-abdominal pressure (straining with urination, cough, constipation, ascites, pregnancy)

Differential Diagnosis

- MINT: Malformation, infectious/inflammatory, neoplastic, traumatic
 - The most common inguinal mass: enlarged lymph nodes or Cloquet’s nodes (femoral triangle)
 - Autoimmune disease, malignancy, or as a response to a localized or systemic infection

Pathology/Pathophysiology

- Reducible hernia: contents can be pushed back through the defect into the peritoneal cavity.
- Incarcerated hernia: contents are stuck in the hernia sac.
- Strangulated hernia: a subset of incarcerated hernia with compromised blood flow to the bowel leading to ischemia.
- Ventral or incisional hernia: at the site of a previous surgery.
- Femoral hernias:
 - Rare, more common in multiparous women and more prone to incarceration/strangulation.
 - Posterior and inferior to the inguinal ligament and medial to the femoral vein.
- Indirect inguinal hernia:
 - The most common hernia in men, women, and children.
 - Congenital (patent processus vaginalis), lateral to inferior epigastric vessels, and through the deep and superficial ring.
- Direct inguinal hernia:
 - More common in older men.
 - Acquired weakness in Hesselbach’s triangle, medial to inferior epigastric vessels, and only through the superficial ring.

Workup

- Inquire about sources of increased straining/intra-abdominal pressure:
 - Urinary retention, constipation, heavy lifting, chronic cough, ascites, and weight gain
- A hernia is considered a clinical diagnosis:
 - No imaging usually needed
- In morbidly obese, diagnosis can be difficult:
 - CT scan when diagnosis unclear

Management

- Asymptomatic hernias can be observed:
 - Exception: femoral hernias.
 - Exception: inguinal hernias in infancy.
 - Wait until preemie is out of the ICU.
- Most inguinal hernias eventually become symptomatic.
- Indirect hernia (most common):
 - Infants: Open the sac (anteriorly), reduce any contents, and perform a high ligation (at the internal ring) of the hernia sac.
 - Adults: Same and add Lichtenstein repair.
- Direct hernia (older men):
 - Do not open sac (no patent processus vaginalis), and reinforce floor with mesh (Lichtenstein) repair or laparoscopic repair.
- Femoral hernia (women):
 - Medial to the femoral vein
 - Inferior to the inguinal ligament
 - High incarceration risk
- Incarcerated hernia:
 - Attempt reduction and then repair semi-electively.
- Strangulated hernia:
 - Urgent surgery
- Umbilical hernia in children:

- Repair if persists > age 4, defect > 2 cm, and progressive enlargement after age 2.
- In adults, definitive treatment of inguinal and femoral hernias typically includes strengthening the floor of the inguinal canal with mesh.

Complications

- Persistent pain from nerve injury is common.
- Recurrence.
- Testicular ischemia:
 - Swollen painful testicle following surgery followed later by testicular atrophy.

Suggested Reading

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Abdominal Pain, Nausea, and Vomiting

Jill Q. Klausner and David C. Chen

Case Study

A 38-year-old woman presents to the emergency department with colicky abdominal pain, nausea, and vomiting for the past day. She has had at least ten episodes of green, bilious emesis without blood. She has had no passage of stool or flatus per rectum since yesterday morning and has not eaten in 24 hours due to the vomiting and abdominal pain. She denies a history of similar symptoms and has no other medical problems. Past surgical history is significant for a cesarean section 2 years ago. Her temperature is 37.8 °C, heart rate is 122/min, blood pressure is 124/78 mmHg, and respiratory rate is 14/min. Her mucous membranes are dry and her abdomen is distended, with a well-healed low transverse abdominal incision. Auscultation reveals high-pitched tinkling bowel sounds. She has mild tenderness throughout the abdomen, but there is no rebound, guarding, or rigidity. No masses or hernias are identified. Rectal examination reveals normal tone, no gross blood, no masses, and no stool in the rectal vault. Laboratory examination is significant for a white blood cell count of $8.2 \times 10^3/\mu\text{L}$ (normal 4.1– $10.9 \times 10^3/\mu\text{L}$), hemoglobin 17 g/dL (12.3–15.7 g/dL), hematocrit 51% (37–46%), sodium 141 mEq/L (135–145 mEq/L), potassium 2.9 mEq/L (3.5–5.0 mEq/L), chloride 93 mEq/L (98–106 mEq/L), bicarbonate 34 mEq/L (24–30 mEq/L), BUN 36 mg/dL (7–22 mg/dL), and creatinine 1.2 mg/dL (0.56–1.0 mg/dL). Urinalysis demonstrates aciduria. Abdominal x-ray is provided in

■ Fig. 3.1.



■ Fig. 3.1 Upright abdominal x-ray with air-fluid levels

Diagnosis

What Is the Differential Diagnosis?

■ Table 3.1

Diagnosis	History and physical
<i>Small bowel obstruction</i>	Colicky abdominal pain, nausea, bilious vomiting, obstipation, abdominal distention, hyperactive bowel sounds (early) or hypoactive bowel sounds (late), prior abdominal surgery
<i>Gastroenteritis</i>	Cramping abdominal pain, fever, nausea, vomiting, diarrhea, hyperactive bowel sounds
<i>Ileus</i>	Diffuse abdominal discomfort but no sharp colicky pain, hypoactive bowel sounds, stool in the rectum, may pass flatus and diarrhea, associated with recent surgery, narcotic use
<i>Large bowel obstruction</i>	Gradually increasing abdominal pain with longer intervals between episodes of pain, abdominal distention, obstipation, less vomiting (feculent), more common in the elderly
<i>Colonic pseudo-obstruction (Ogilvie's syndrome)</i>	Debililitated hospitalized medical or surgical patients; abdominal pain, nausea, vomiting, may continue to pass flatus, massive abdominal distention without mechanical obstruction; idiopathic
<i>Acute mesenteric ischemia</i>	Pain out of proportion to physical exam; nausea, vomiting, anorexia, atrial fibrillation

What Is the Most Likely Diagnosis?

The history of acute onset of colicky abdominal pain, nausea, vomiting, and obstipation in a young patient with prior abdominal or pelvic surgery is highly suggestive of simple mechanical *small bowel obstruction* (SBO) due to adhesions from prior surgery. This patient presents with uncomplicated or *simple* SBO. Treatment is necessary in order to avoid progression and potential complications such as strangulation, bowel necrosis, sepsis, and even death. This patient also presents with severe volume depletion as evidenced by dry mucous membranes, prerenal azotemia (BUN/creatinine ratio >20), and a *hypochloremic, hypokalemic metabolic alkalosis* as a result of volume losses from recurrent emesis and third spacing secondary to SBO.

Watch Out

A high bicarbonate level in the setting of vomiting is highly suggestive of metabolic acidosis.

History and Physical Exam

What Is the Significance of SBO in the Absence of an Abdominal Scar?

The absence of an abdominal scar markedly lowers the likelihood of adhesions, the most common etiology of SBO in the USA. Adhesions typically result from prior surgeries but may

rarely form due to prior abdominal infections, such as pelvic inflammatory disease or intestinal perforation. The majority of SBOs due to intra-abdominal adhesions will resolve with conservative treatment. On the other hand, most other causes of SBO are very likely to require surgical intervention and often emergently. Thus, without an abdominal scar, there's a high likelihood the patient will need surgical intervention.

Watch Out

Hernias are the most common cause of SBO worldwide. Always make sure to examine the groins, the umbilicus, and the femoral region for masses in patients presenting with signs/symptoms suggestive of SBO.

Watch Out

In a patient presenting with a history and exam suggestive of SBO, make sure to ask or look for abdominal scars from prior surgery (e.g., C-section scar may be under the belt line or small incisions from laparoscopic procedures).

absence of bowel sounds, and localized abdominal tenderness. Occasionally, a painful mass or blood in the stool may be found. Unfortunately, these signs are not particularly sensitive or specific for early strangulation, but they should alert one to the possibility of strangulation and the need for early surgical intervention.

Watch Out

The four cardinal signs of strangulated bowel: fever, tachycardia, leukocytosis, and localized abdominal tenderness.

Pathophysiology

What Is a Closed Loop Obstruction?

A *closed loop obstruction* is a particularly dangerous form of bowel obstruction in which a segment of intestine is obstructed both proximally and distally. Vomiting will not relieve the obstruction nor will a nasogastric tube, as gas and fluid accumulates within this segment of bowel and cannot escape. This progresses rapidly to strangulation with risk of ischemia and perforation.

What Is the Howship-Romberg Sign?

This is suggestive of an obturator hernia and consists of pain in the medial aspect of the thigh with abduction, extension, or internal rotation of the hip due to compression of the obturator nerve by an obturator hernia (pelvic hernias seen mostly in elderly multiparous females and in those with significant weight loss).

What Is the Significance of Severe Abdominal Pain and Localized Tenderness in Association with an SBO?

Severe abdominal pain and/or localized tenderness in association with SBO are suggestive of complicated or *strangulated* SBO. In contrast to a simple SBO where blood flow to the bowel remains intact, strangulated obstruction occurs when vascular perfusion is impaired, leading to intestinal ischemia and ultimately necrosis and perforation. Strangulation accounts for almost half of all deaths due to SBO and increases the morbidity rate significantly. Early surgical intervention is essential to avoid morbidity and poor outcomes. Strangulated obstruction typically presents with continuous (as opposed to intermittent) abdominal pain, signs of a systemic response (fever, tachycardia, leukocytosis), peritoneal signs, acidosis,

What Is the Pathophysiology of SBO?

In SBO, gas and fluid accumulate proximal to the site of obstruction, causing dilation of the bowel followed by increased diffuse motility in attempt to overcome the obstruction. The increased peristaltic activity that attempts to overcome the obstruction in the early course of SBO causes the characteristic colicky pain. Since the increased motility is not localized, patients with SBO can present with diarrhea. The small bowel distention stretches visceral peritoneum, resulting in autonomic stimulation with progressive nausea and emesis. Failure to pass gas or stool per rectum is typically due to a complete mechanical obstruction of the small intestine.

Are Bowel Sounds Helping in Diagnosing SBO?

Theoretically, bowel sounds are initially increased and should have a high-pitched, tinkling sound. As the bowel distends and intramural pressures rise, intestinal motility decreases, and bowel sounds diminish. Clinically, auscultation of bowel is not as useful in clinical practice when differentiating normal versus pathologic bowel sounds. In the presence of intestinal ischemia or perforated bowel, the bowel sounds may become absent.

What Are the Most Common Causes of an SBO?

Table 3.2

Cause of SBO	Distinguishing features
<i>Intra-abdominal adhesions</i>	Most common cause <i>in the USA</i> ; associated with prior abdominal or pelvic surgery
<i>Hernia</i>	Most common cause <i>worldwide</i> (newly immigrated patient); bulge in groin or abdominal wall
<i>Crohns</i>	Terminal ileitis, strictures, perianal fistula, abscess, fissures; aphthous ulcers
<i>Gallstone ileus</i>	Elderly female; pneumobilia (air within biliary tree) seen on CT, possible large calcification (gallstone) on plain film in RLQ near the ileocecal valve
<i>Intussusception</i>	Target sign seen on CT; in adults, lead point is often a mass or tumor
<i>Neoplasm</i>	History of cancer; mass seen on CT
<i>Volvulus</i>	Whirl sign seen on CT
<i>Radiation-induced stricture</i>	History of pelvic radiation (e.g., prostate, gynecologic cancers)

RLQ right lower quadrant, CT computed-tomography

What Is the Risk of Developing SBO After Different Operations?

In general, lower abdominal operations have higher risk for SBO, compared to upper abdominal operations. Adhesions after pelvic operations are responsible for more than 60% of all SBOs in the USA, with appendectomy being the most common cause, followed by colorectal resection, and then gynecologic procedures. Adhesions are caused by infection, foreign material (sutures), tissue ischemia, or handling of the bowel. Inflammatory processes such as appendicitis and diverticulitis create adhesions as surrounding intestinal loops attempt to contain the source of inflammation and infection. Disruption of the visceral and parietal peritoneum with pelvic operations leads to adhesions, especially in the dependent positions where the loops of the small intestine rest. Another possible explanation for the higher rate of SBOs after pelvic operations compared to abdominal operations is that the bowel is more mobile in the pelvis than in the upper abdomen and thus more likely to produce an obstructing torsion.

Does Laparoscopic Surgery Have a Lower Risk for SBO Compared to Open Surgery?

Not always. One would expect the smaller incisions and minimally invasive dissections involved in laparoscopic surgery to be associated with a lower rate of postoperative adhesions and subsequent SBO. However, SBO following laparoscopic abdominal surgery can occur irrespective of the type of operation with the highest being in those undergoing laparoscopic cholecystectomy and appendectomy. In some cases, laparoscopic repair has a higher risk for subsequent SBO, compared to an open repair (e.g., hernias).

What Are the Mechanisms of Fluid Loss in SBO?

Volume depletion is a common finding in SBO, but the mechanisms of fluid loss differ depending on the site and degree of obstruction. With proximal obstructions, repeated episodes of emesis as well as refusal of oral intake due to anorexia contribute to volume depletion and electrolyte abnormalities. With a complete obstruction, there is a transudative loss of fluid into the peritoneal cavity. The intestine proximal to the site of obstruction becomes distended due to the accumulation of gastrointestinal secretions and gas. Stasis in the intestinal lumen results in bacterial overgrowth, which causes even more dilation due to bacterial fermentation. As the hydrostatic pressure within the intestinal lumen increases, fluid accumulates in the bowel wall, altering the Starling forces of capillary fluid exchange such that there is a net filtration of fluid, electrolytes, and protein into the bowel wall and lumen. This loss of fluid from the intravascular space is termed *third spacing* and contributes to volume depletion in both proximal and distal SBO.

What Is the Mechanism of Aciduria in Patients with Ongoing Emesis?

The above patient presents with a hypochloremic, hypokalemic metabolic alkalosis as a result of volume losses from recurrent emesis. The volume loss activates the renin-angiotensin-aldosterone system to increase sodium and water absorption from the distal convoluted tubules in the kidneys. In order to maintain ion balance, potassium is excreted in exchange for sodium. As the patient becomes progressively more hypokalemic (which can lead to arrhythmias), the kidney will eventually excrete hydrogen ions instead of potassium ions, which perpetuates the systemic metabolic alkalosis and results in a *paradoxical aciduria*. This occurs in all processes that involve persistent emesis/volume loss (e.g., pyloric stenosis).

Workup

What Laboratory Tests Should Be Obtained in the Initial Workup for SBO?

When working up SBO, it is important to obtain a complete blood count, chemistry panel, and serum lactate. While laboratory values do not play a significant role in the diagnosis of SBO, they are essential in assessing the degree of volume depletion and may raise the suspicion of bowel ischemia. Volume-depleted patients may exhibit hemoconcentration, as evidenced by elevated hemoglobin and hematocrit. A ratio of BUN/creatinine >20 is suggestive of prerenal azotemia, which can be caused by decreased blood flow to the kidneys. A chemistry panel can also assess for hypochloremic, hypokalemic metabolic alkalosis, which often results from repeated bouts of emesis. Leukocytosis raises the possibility of an infectious etiology or bowel compromise, changing the management algorithm of a simple SBO. An elevated serum lactate (or low serum bicarbonate), particularly associated with a non-anion gap metabolic acidosis, may indicate an ischemic bowel, as does hyponatremia.

What Imaging Is Recommended for an SBO?

When SBO is suspected, initial imaging should include an abdominal series (■ Table 3.3), generally followed by an abdominal and pelvic CT with oral and intravenous contrast.

Watch Out

Remember what three films comprise an abdominal series (upright chest x-ray, upright abdominal x-ray, and supine abdominal X-ray [also termed KUB]). If the patient is critically ill and unable to sit upright, a left lateral decubitus film is substituted.

■ Table 3.3 Abdominal series

Films	Purpose
Upright chest radiograph	Rule out free air
Upright abdominal radiograph	Look for air-fluid levels
Supine abdominal radiograph	Determine amount of distention (width of small bowel)

How Do You Differentiate Large and Small Bowel on Radiographs?

The small bowel has lines (plicae circulares) going all the way around the circumference of the bowel. The large bowel has lines (haustra) traversing only *halfway* through the bowel.

What Are the Different Radiologic Findings Associated with SBO?

■ Table 3.4

Radiologic finding	Radiologic appearance	Associated pathology in context of SBO
SBO (abdominal series)	Dilated loops of small intestine (plicae circulares), air-fluid levels, bowel stacking	Classic radiographic findings of SBO
Target sign (CT)	Three concentric circles, with hyperdense inner and outer rings and a hypodense middle ring	Intussusception
Whirl sign (CT)	Twist of bowel wrapped around a single constrictive foci of mesentery or adhesion	Small bowel volvulus
Pneumatosis (CT)	Presence of gas within the wall of the intestine	Strangulated obstruction leading to intestinal ischemia and necrosis
Portal venous gas (CT)	Air in the periphery of the liver due to centrifugal portal flow	Late presentation of pneumatosis with air passing via portal venous circulation

How Is a Complete SBO Different from a Partial SBO? Why Is It Important to Distinguish Between the Two?

In a *complete* SBO, the intestinal lumen is entirely occluded, and there is no passage of gas or fluid. In a *partial* SBO, gas and fluid are able to pass. Patients with a complete SBO present with colicky abdominal pain, nausea, vomiting, and obstipation. Those with a partial SBO develop similar symptoms, but more slowly, and continue to pass gas and stool beyond 6–12 hours after symptom onset. While plain films of a patient with complete SBO show dilated loops of bowel with air-fluid levels and no gas in the rectum, those with partial SBO *will show residual colonic gas*. Sometimes plain films will be equivocal, and CT

will be necessary in order to visualize the amount of residual air and fluid in the distal intestine. It is important to distinguish between a complete and partial SBO because the management of these two conditions is different. The risk of strangulation is minimal for patients with partial obstruction, whereas the risk is substantial for those with complete obstruction. Thus, a partial SBO can typically be managed nonoperatively, while complete SBO may require earlier surgical intervention.

How Do You Distinguish SBO from LBO?

The clinical presentation of large bowel obstruction (LBO) is dependent upon location and etiology of obstruction. If the proximal colon is involved, it is more likely to be mistaken for SBO (assuming the ileocecal valve is incompetent) as the small intestine will become dilated too causing a similar clinical presentation. If a tumor is the cause of LBO, the course may be more insidious in onset, and symptoms may be chronic with less likelihood of confusion with SBO. In general, LBO causes gradually increasing abdominal pain, progressive distention, constipation, and occasionally feculent vomiting. There are longer intervals between episodes of cramping pain, and there is more pain in the suprapubic area with LBO than with SBO. Common causes of LBO include colon cancer, diverticular disease, and volvulus. On imaging, an “apple-core” lesion is characteristic of colon cancer, and a “coffee-bean” or “omega sign” tapering down toward the left lower quadrant is characteristic of sigmoid volvulus.

Watch Out

An obstructing sigmoid colon cancer can lead to a closed loop obstruction if the ileocecal valve is functional, as gas cannot exit into the small bowel or from rectum. A functional ileocecal valve is present in up to 80% of the population.

How Do You Distinguish Between Postoperative Ileus and SBO?

In the early postoperative period, it is important to distinguish between an obstruction, which occurs in less than 1% of those undergoing laparotomy, and an ileus, which is considered as the most common postoperative complication. After abdominal surgery, GI motility is reduced due to a number of factors including a stress-induced sympathetic response, the release of inflammatory mediators, and the use of anesthetic and analgesic agents. The small intestine usually regains normal motility within the first 24 hours after surgery, the stomach takes 48 hours, and the colon can take as long as 3–5 days. This phenomenon is physiologic and is referred to as *postoperative ileus*. It may be difficult to distinguish postoperative ileus from early SBO, since postoperative ileus also presents with

abdominal pain, nausea, vomiting, and abdominal distention. Ileus, however, usually presents with absent or hypoactive bowel sounds, and the pain is described as dull and constant. One should suspect SBO if bowel function initially returned and subsequently the patient developed obstructive symptoms. Plain films should reveal dilated loops of bowel but no air-fluid levels in ileus. If x-rays are nondiagnostic, CT is very effective in differentiating SBO from postoperative ileus and will often reveal the etiology of postoperative SBO in many cases.

Watch Out

Gallstone ileus is a misnomer as this is a type of mechanical SBO where a large gallstone travels through a cholecystoduodenal fistula and becomes impacted in the narrower caliber distal small bowel near the ileocecal valve.

Management

What Are the Initial Steps in the Management of an SBO?

Patients with SBO are often significantly volume depleted. Aggressive fluid resuscitation (with an isotonic intravenous fluid such as normal saline) and electrolyte repletion are critical initial steps in the management. Additionally, early placement of a nasogastric (NG) tube to evacuate air and fluid is important because gastric decompression will decrease nausea, vomiting, distention, and the risk of aspiration. The more significantly ill patient should have an indwelling bladder catheter placed to monitor hourly urine output.

What Is the Role of Gastrografin in the Management of SBO?

Early administration of oral contrast has been used for diagnostic and therapeutic purposes in the management of SBO. Passage of contrast to the large intestine predicts resolution and expedites the course of nonoperative management. Lack of passage predicts failure of conservative management, and early intervention improves outcomes and expedites management. The high osmotic load of oral contrast may help to resolve early partial SBO, as Gastrografin increases intraluminal water content and decreases bowel wall edema. Evidence is limited, but results from a recent multi-institutional, prospective observational study suggest that patients with SBO due to adhesions may benefit from Gastrografin, with lower rates of operative intervention and shorter length of stay in the hospital.

Watch Out

Gastrografin enema is also useful in resolving meconium obstruction in neonates.

Operative Versus Nonoperative Management of SBO

In the absence of peritonitis or evidence of bowel ischemia, patients with an SBO due to adhesions should first undergo an initial period of NG tube decompression and fluid and electrolyte resuscitation. If the patient develops symptoms or signs of bowel compromise (increasing abdominal pain and tenderness on exam), the patient should then promptly be taken to the operating room. In the absence of such signs, it should be determined whether the SBO is partial or complete. The management of partial SBO is an initial trial of nonoperative management due to the fact that progression to strangulation is unlikely. Studies have shown that 60–85% of patients with partial obstruction will have resolution of symptoms without the need for surgery. However, if a patient with partial SBO begins to clinically deteriorate, prompt operative intervention may be necessary. The management of complete SBO or of a patient with evidence of ischemic bowel is urgent surgical intervention.

What Should You Do if You Suspect Nonviable Bowel During Laparotomy for SBO?

Necrotic bowel generally does not occur in association with an SBO unless there is a closed loop obstruction. Any bowel that is obviously nonviable needs to be resected. If there are segments of bowel of questionable viability, there are several methods to assess viability. These methods include looking at the color (pink versus pale or bluish), peristalsis versus no peristalsis, and presence/absence of arterial pulsations in the mesentery. In addition, the bowel can be interrogated using a hand-held Doppler to detect audible arterial signals on the antimesenteric border of the questionable bowel. Finally, intravenous fluorescein dye can be administered. Viable bowel will take up the dye, which can then be seen using an ultraviolet (Wood's) lamp. If the viability remains in question, and it is a small segment, the segment should be resected. If there is a large segment of questionable viability (where resecting it could lead to short gut syndrome), the bowel can be left intact, the abdomen is kept open (with a negative pressure wound covering), and a second-look operation is performed to assess viability the following day after the patient has been warmed and further resuscitated.

What Is the Management of Early Postoperative SBO?

Early postoperative SBO is uncommon, and most can be managed nonoperatively. If the diagnosis of acute postoperative SBO is made, an attempt to classify it as partial or complete is needed. Although most early postoperative SBO are partial obstructions, one must be able to detect complete obstruction

to prevent serious complication or bowel compromise. Partial obstruction should be managed conservatively, and in the postoperative setting, up to 3 weeks of nonoperative therapy may be acceptable. If there is a complete obstruction, one may initiate a trial of conservative management, only proceeding to the operating room for cases of suspected strangulation or lack of improvement after 24 hours of conservative management. Unique to the management of the postoperative SBO is the issue of timing. Traditionally, unless there is clear evidence of peritonitis or bowel compromise, reoperation is avoided until after 10–14 days postoperatively because early adhesions tend to be very dense and highly vascularized, making reoperation difficult and dangerous (with a high likelihood of injuring the bowel). Successful conservative management in these cases will ideally push elective intervention out 4–6 weeks when adhesions will remodel, making reoperation less morbid or allowing for avoidance of reoperation altogether.

Areas Where You Can Get in Trouble

Nausea and Vomiting Months to Years After Gastric Bypass

Although intra-abdominal adhesions are the most common cause of SBO in the USA, this is not true for patients following gastric bypass surgery. The most common cause of SBO in these patients is an *internal hernia*. Internal hernias most commonly form when bowel herniates through defects in the mesentery. Gastric bypass involves creating a Roux limb of small bowel that is connected to the stomach. A defect in the mesentery is created to pass the limb. This type of internal hernia is called a Petersen's space hernia. They may or may not present with abdominal distention. Laparoscopic gastric bypass repair has higher risk for internal herniation compared to its open gastric bypass. This may seem counterintuitive because laparoscopic surgery leads to a lower rate of postoperative adhesions. However, in the case of internal herniation, the formation of adhesions may serve as a protective role in preventing bowel mobility and the potential herniation into Petersen's space. Patients suspected of an internal hernia that are stable should be worked up with a CT abdomen/pelvis and undergo urgent surgical intervention. If the patient has evidence of peritonitis, the patient should go directly to surgery.

Abdominal Complaints in Opioid Drug Users

Patients that abuse opioids (e.g., IV heroin, oral narcotics, etc.) often have abdominal complaints ranging from bloating, distention, constipation, and diarrhea to generalized vague abdominal pain or discomfort. Chronic opioid users develop opioid-induced constipation, which is the most common adverse effect associated with prolonged use of opioids. In contrast, opioid users going through withdrawal

may have increased GI motility and present with diarrhea. This may make it difficult to discern if serious abdominal pathology (e.g., small bowel obstruction, mesenteric ischemia) is present in a patient that may be abusing opioids or is in withdrawal. Physical exam findings that will help differentiate opioid withdrawal from an acute abdominal process include the presence of *mydriasis*, *rhinorrhea*, and *diaphoresis* in those presenting with opioid withdrawal.

Summary of Essentials

History and Physical Exam

- Acute onset of colicky abdominal pain, nausea, vomiting, and obstipation
- History of previous pelvic or abdominal operations
- Examine for hernias

Pathophysiology

- Most common cause of SBO in the USA is intra-abdominal adhesions from prior surgery.
- Gas and fluid accumulate proximal to the site of obstruction.
- Ongoing emesis and third spacing lead to volume depletion, prerenal azotemia, and hypochloremic, hypokalemic metabolic alkalosis.

Diagnosis

- Classic radiographic findings of SBO: dilated loops of small intestine, air-fluid levels, bowel stacking.
- CT can distinguish between postoperative ileus and SBO and can reveal the etiology of SBO.

Management

- Initial treatment includes fluid resuscitation, electrolyte repletion, and placement of a nasogastric tube.
- Majority of patients with partial obstruction will not need surgery.
- Patients with complete obstruction may manage conservatively for 12–24 hours, but if no clinical improvement, surgical intervention is warranted.
- Immediately proceed to operating room if any signs or symptoms of peritonitis or bowel ischemia.
- Nonviable bowel must be resected.
- Avoid reoperation on early postoperative SBO unless clear evidence of peritonitis or bowel compromise.

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Right Leg Pain, Swelling, and Erythema for Two Days

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Case Study

A 40-year-old male with diabetes mellitus and hepatitis C-related cirrhosis presents to the emergency department with a 2-day history of right leg pain, redness, and swelling. He states that he thinks he may have been bitten in the leg by a bug while sleeping. On physical examination, his temperature is 37.8 °C, heart rate is 110/min, blood pressure is

90/60 mmHg, and respiratory rate is 18/min. His right leg is markedly swollen as compared to the left. The skin overlying the calf region is erythematous, with one 3 cm bullae, and an area of violaceous skin. There is no palpable crepitus. Plain X-ray of the leg demonstrates gas bubbles within the soft tissue in the calf. The foot itself is pink and warm, with normal

pulses. Laboratory values are significant for a BUN of 40 mg/dL (normal 7–20 mg/dL), serum glucose of 200 mg/dL (70–100 mg/dL), creatinine of 1.6 mg/dL (0.8–1.4 mg/dL), white blood cell (WBC) count of $24 \times 10^3/\mu\text{L}$ ($4.1\text{--}10.9 \times 10^3/\mu\text{L}$), hemoglobin of 9.5 g/dL (13.8–17.2 g/dL), and a serum sodium of 128 mEq/L (136–144 mEq/L).

Diagnosis

What Is the Differential Diagnosis?

Table 4.1

Condition	Comments
<i>Necrotizing soft tissue infection (NSTI)</i>	Acute infection of the deep fascia, often with crepitus, bullae, and necrosis of the subcutaneous tissue, mixed flora
<i>Cellulitis</i>	Infection of the deep dermis and subcutaneous fat presenting with redness and erythema without the tissue destruction characteristics of NSTI
<i>Cutaneous anthrax</i>	Painless or pruritic eschar surrounded by edema
<i>Hypersensitivity reaction</i>	No fever or leukocytosis; history of exposure to plants or animals
<i>DVT</i>	Usually involves the leg, look for history of hypercoagulability, immobility, and/or inflammatory state (e.g., postsurgical, malignancy)
<i>Sweet's syndrome (acute febrile neutrophilic dermatosis)</i>	Acute eruption of tender erythematous plaques with vesicles, fever, and neutrophilia; classically caused by treatment with G-CSF; may involve almost any other organ system, particularly respiratory and GI tracts; also associated with pregnancy and malignancy
<i>Pyoderma gangrenosum</i>	Neutrophilic infiltration of the skin; exquisitely painful lesions; may involve almost any other organ system, associated with inflammatory bowel disease
<i>Erythema multiforme</i>	Erythematous or purpuric plaques and bullae with central clearing; involves the extremities, palms, and soles; associated with herpes simplex virus, mycoplasma, and malignancy
<i>Stasis dermatitis</i>	Dermal fibrosis and brawny edema secondary to venous incompetence; may become acutely inflamed with crusting and exudate; look for evidence or history of venous incompetence and DVT

G-CSF granulocyte colony-stimulating factor, DVT deep vein thrombosis, GI gastrointestinal, NSTI necrotizing soft tissue infection

What Is the Most Likely Diagnosis?

In a diabetic patient presenting with a painful, erythematous, swollen leg with bullae and violaceous skin along with radiographic evidence of gas bubbles within the soft tissues of the leg, the most likely diagnosis is necrotizing soft tissue infection (NSTI).

History and Physical

What Is the Implication of Crepitus?

Crepitus implies the presence of gas within the tissues, most likely due to the presence of gas-forming organisms.

What Are the Risk Factors for NSTI?

Factors that depress immunity and/or decrease tissue perfusion increase the risk for NSTI including diabetes mellitus, malnutrition, intravenous (IV) drug abuse, obesity, chronic alcohol abuse, chronic lymphocytic leukemia, chronic steroid use, renal failure, peripheral arterial disease, and cirrhosis.

Watch Out

NSTI can also develop in postsurgical wounds, as well as following traumatic extremity injuries, particularly in association with gross wound contamination.

What Is the Implication of Bullae? Violaceous Skin?

The presence of bullae implies partial tissue death within the layers of the skin that allows for the collection of fluid between tissue layers. Violaceous skin (a violet or purple discoloration) implies ischemia.

What Are the “Hard Signs” of NSTI? What Percent of Patients with NSTI Have Such Hard Signs?

Hard signs are signs that, if present, indicate that the disease is present. Crepitus, skin necrosis, bullae, or gas on X-ray are considered “hard signs” of NSTI when seen in association with a soft tissue infection. However, it has been shown that less than half of patients with NSTI will have hard signs.

Watch Out

NSTI may present with pain *out of proportion* to physical exam or cutaneous anesthesia (indicating necrosis of nerves/muscles).

Why Is It Important to Distinguish Between Cellulitis and NSTI? How Do Laboratory Values Help?

Cellulitis and NSTI are surprisingly difficult to distinguish based on physical exam. Treatment of NSTI requires *emergent* surgical debridement of all infected tissue, whereas cellulitis simply requires antibiotics. As such, a high level of suspicion is required for a prompt diagnosis. A low serum Na or a very high WBC count is strongly suggestive of NSTI. The Laboratory Risk Indicator for Necrotizing Fasciitis (LRINEC) score has been developed in order to distinguish NSTI from other soft tissue infections (■ Table 4.2).

Pathophysiology

What Is the Spectrum of NSTI?

NSTI can involve the skin and subcutaneous tissue (necrotizing cellulitis), the fascia (necrotizing fasciitis), and/or the muscle (necrotizing myositis). Another term used for necrotizing myositis is gas gangrene.

■ Table 4.2 LRINEC score

Feature
C-reactive protein > 150 mg/L
WBC > $15 \times 10^3/\mu\text{L}$
Hemoglobin > 13.5 g/dL
Na < 135 mEq/L
Creatinine > 1.6 $\mu\text{mol/L}$
Glucose > 180 mg/dL

What Are the Typical Organisms Seen in NSTI?

NSTI may be monomicrobial or polymicrobial, and a classification scheme based on the infectious agent has been developed. Type-I NSTI is a *polymicrobial* infection and accounts for 70–80% of all NSTI cases. Of those caused by a single organism, the most common ones are *Staphylococcus aureus* (most common) and *Klebsiella*. *C. perfringens* is a rare cause of NSTI (and the classic organism associated with gas gangrene). Type II NSTI is an infection with group A *Streptococcus* with or without *Staphylococcus*.

What Is the Implication of Culturing *Clostridium septicum* From the Wound?

Clostridium septicum infection can lead to gas gangrene and is associated with occult malignancies, most often colon cancer and hematologic malignancies.

What Is the Term for NSTI that Involves the Scrotum and/or Perineum?

Fournier’s gangrene.

Management

What Are the Initial Steps in the Management of NSTI?

The initial treatment of a patient with suspected NSTI consists of intravenous fluids, broad-spectrum IV antibiotics, and aggressive emergent surgical debridement, which is the gold standard to confirm the diagnosis and for the treatment for NSTI.

How Do You Determine How Much Tissue to Debride?

All soft tissues, including the skin, subcutaneous fat, fascia, and muscle, that show any evidence of infection must be extensively debrided to the point of *seeing healthy bleeding tissue*. It is not acceptable to leave behind a tissue that is of borderline viability, as the infection will often continue to extend postoperatively.

What If Extensive Muscle Necrosis Is Found?

If extensive muscle necrosis is discovered during surgery, amputation may be necessary.

What Are the Intraoperative Findings that Confirm NSTI?

Operative findings in NSTI include murky fluid (i.e., dish-water fluid), gray discoloration of the fascia, and lack of bleeding from the fascia. Additionally, the fascia may separate from the muscle easily, without the normal resistance on digital exploration.

What Is the Role of a Second-Look Operation?

Current recommendations are that a second-look operation should be scheduled 24 hours after the initial debridement to ensure that the infection has not reemerged. Patients may require multiple reoperations after the initial debridement.

What Do You Do If Your Suspicion for NSTI Is High But You Are Not Certain of the Diagnosis?

If the diagnosis of NSTI is uncertain, yet the suspicion is high, surgical exploration is undertaken, as this is the gold standard of both diagnosis and treatment. The incision must be taken down to the fascia and muscle so both can be inspected.

Is Imaging Beneficial in the Diagnosis of NSTI?

When the diagnosis is in question, plain X-rays are useful if they demonstrate gas in the soft tissue. However, most cases of NSTI do not demonstrate gas on plain films. CT scan may also be beneficial. The primary finding to look for on CT imaging in patients with NSTI is *gas within deep tissues*.

What Is the Anticipated Mortality Risk Associated With NSTI?

The overall mortality rate for NSTI is a very high, averaging 25%. The mortality has been largely unchanged for the past century. However, it is consistently lower in pediatric patients compared to adults.

Area Where You Can Get in Trouble

Postsurgical Wound With Dishwater Purulent Fluid

This is a rare but well-known complication after surgery, and the description of dishwater pus is classic for *postoperative clostridial wound infection*. The two most common organisms

causing early postoperative necrotizing soft tissue infection are *Clostridium perfringens* and *Streptococcus pyogenes*. Like all cases of NSTI, the most important steps in management are IV fluids, broad-spectrum antibiotics, and emergent surgical debridement.

Watch Out

In cases of NSTI caused by *Clostridium perfringens*, the patient should also be given clindamycin in addition to broad-spectrum IV antibiotics. Clindamycin has been demonstrated to decrease the amount of alpha-toxin produced by *Clostridium*, which decreases its virulence.

Area of Controversy

What Is the Role of Hyperbaric Oxygen?

The use of hyperbaric oxygen remains controversial but is a potential adjuvant therapy to aggressive surgical debridement and ICU care in the treatment of NSTI. A recent small study showed that hyperbaric oxygen reduced mortality in NSTI from 34% to 12%. However, hyperbaric oxygen should not replace or delay aggressive surgical debridement.

Summary of Essentials

History and Physical Examination

- Most present without a clear history of traumatic injury, even a small cut.
- Acute onset of pain, swelling, and erythema.
- Hard signs occur in less than half of patients.
 - Air on plain X-ray
 - Crepitus
 - Bullae
 - Skin necrosis

Diagnosis

- NSTI is a clinical diagnosis.
- Low serum sodium and very high WBC.
- LRINEC score can help distinguish NSTI instead of less life-threatening soft tissue infections.

Management

- Immediate treatment includes IV fluids, broad-spectrum antibiotics, and emergent aggressive surgical debridement.
- Multiple reoperations for further debridement are often necessary.
- Delay in recognition and treatment lead to increase in mortality.

Suggested Reading

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Question Set: Acute Care Surgery

Questions

1. A 65-year-old obese male with diabetes and a history of IV drug abuse presents with a painful swollen left leg. Exam reveals dark purple discoloration and several large bullae over the calf. On physical exam, his temperature is 38.3 °C, heart rate is 120/min, and blood pressure is 92/68 mmHg. The CRP is 200 mg/L (normal < 10 mg/L), and the white blood cell (WBC) count is $28.3 \times 10^3/\mu\text{L}$ (normal $4.1\text{--}10.9 \times 10^3/\mu\text{L}$). Creatinine is 2.0 mg/dL (normal 0.5–1.5 mg/dL), and Na is 127 mEq/L (normal 135–145 mEq/L). Distal pedal pulses are 1+. IV fluids and IV broad-spectrum antibiotics are administered. Which of the following is the next best step?
- (A) X-ray of the leg
 - (B) CT scan of the leg with IV contrast
 - (C) Venous duplex scan of the left leg
 - (D) Measure compartment pressures
 - (E) Emergent wide surgical debridement
2. A 66-year-old woman presents to her family doctor complaining of a pain in her left groin that has appeared intermittently over the past several months. On physical exam, a soft mass is palpated in her left groin, below the inguinal ligament, and near her femoral pulse. On palpation, the mass is soft and slightly tender and disappears with gentle compression. Which of the following is true regarding these types of hernias?
- (A) They are the most common hernia type in women.
 - (B) The risk of strangulation is relatively low.
 - (C) The hernia sac travels lateral to the femoral vein.
 - (D) If discovered incidentally and the patient is asymptomatic, repair is not indicated.
 - (E) It is associated with multigravida.
3. Following open right inguinal hernia repair, a 50-year-old male complains of numbness and burning pain on the right scrotal side. This most likely represents injury to:
- (A) The genital branch of the genitofemoral nerve
 - (B) The femoral branch of the genitofemoral nerve
 - (C) The ilioinguinal nerve
 - (D) The lateral femoral cutaneous nerve
 - (E) The iliohypogastric nerve
4. A 65-year-old male presents to the ED with nausea, vomiting, and severe abdominal pain. Past history is significant for prior sigmoid colectomy for diverticulitis 10 years ago. On physical exam, his temperature is 37.9 °C, blood pressure is 110/80 mmHg, and heart rate is 110/min. His abdomen has a well-healed midline scar and is distended. Bowel sounds are hyperactive with occasional rushes and tinkles. He has marked right upper quadrant (RUQ) tenderness to palpation with guarding. The rest of the abdominal exam is unremarkable. Abdominal series x-rays demonstrates one loop of markedly distended small bowel in the RUQ with an air-fluid level. No gas is seen in the colon or rectum. Laboratory values demonstrate a WBC of $18 \times 10^3/\mu\text{L}$ (normal $4.1\text{--}10.9 \times 10^3/\mu\text{L}$) with 15% bands and a serum lactate of 5 mmol/L (normal

0.5–1.6 mmol/L), BUN 30 mg/dL (7–21 mg/dL), and creatinine 1.2 mg/dL (0.5–1.4 mg/dL). Amylase, lipase, and liver chemistries are normal. Nasogastric tube and IV fluids are given. What is the next step in the management?

- (A) Exploratory laparotomy
- (B) Admit for close observation
- (C) Upper GI with small bowel follow through with barium
- (D) Upper GI with small bowel follow through with Gastrografin
- (E) Abdominal ultrasound

5. One day following extensive debridement of the right leg for a necrotizing soft tissue infection (NSTI), a 40-year-old male remains in the ICU, intubated, and requiring 70% FIO₂. WBC count has risen from a preoperative level of $16 \times 10^3/\mu\text{L}$ (normal $4.1\text{--}10.9 \times 10^3/\mu\text{L}$) to $34 \times 10^3/\mu\text{L}$. Serum lactate has also risen. Which of the following is the best next step in treatment?
- (A) Second-look operation
 - (B) Amputation of the right leg
 - (C) Broaden antibiotic coverage
 - (D) CT scan of the leg
 - (E) Start vasopressor
6. A 30-year-old woman is recovering from an open cholecystectomy in the hospital. On the second postoperative day, she begins to complain of cramping abdominal pain without vomiting. She has no past medical or surgical history, and her postoperative course has been unremarkable. She is receiving oral hydrocodone for pain and is on a clear liquid diet. She has a temperature of 37.8 °C, blood pressure is 128/84 mmHg, and pulse is 82/min. Her physical exam is significant for absent bowel sounds, a mildly distended abdomen with mild diffuse tenderness without rebound or guarding. Which of the following is the best next step in management?
- (A) Encouraging ambulation
 - (B) Placement of a nasogastric tube
 - (C) Neostigmine
 - (D) Conversion of hydrocodone to a nonsteroidal anti-inflammatory drug (NSAID)
 - (E) Return to the operating room for exploration
7. A Richter's hernia:
- (A) Describes a hernia in which a retroperitoneal organ protrudes into the hernia sac
 - (B) Has a low risk of incarceration
 - (C) Most commonly presents as a small bowel obstruction (SBO)
 - (D) Can mislead the clinician as strangulated bowel can easily be missed
 - (E) Should be manually reduced in the emergency department provided there is no evidence of bowel obstruction
8. A 55-year-old schizophrenic homeless man arrives to the ED with abdominal pain and vomiting. He reports that the abdominal pain started yesterday and has been worsening. He is afebrile, blood pressure is 122/86 mmHg, and heart rate is 116/min. In the ED he vomits green emesis without blood. His last bowel movement was 48 hours ago. Physical examination reveals a large scar in his right upper quadrant. On abdominal examination, the abdomen is distended, with hyperactive bowel sounds, and is tympanic to percussion, with mild diffuse tenderness, and no rebound or guarding. WBC is $9 \times 10^3/\mu\text{L}$ (normal $4.1\text{--}10.9 \times 10^3/\mu\text{L}$). Abdominal series shows dilated loops of bowel with multiple air-fluid levels. After fluid resuscitation, what is the most appropriate next step in management?
- (A) Nasogastric tube suction
 - (B) Laparoscopy
 - (C) Exploratory midline laparotomy
 - (D) Intravenous erythromycin
 - (E) CT scan of the abdomen

9. A worried mother presents to you with concerns that her 6-month-old boy has a large protrusion at his belly button that is worse when he cries but reduces when he is sleeping. On exam you palpate a 1 cm fascial defect at his umbilicus. Which of the following is true about this condition?
- (A) Elective repair is recommended.
 - (B) The condition is associated with cardiac anomalies.
 - (C) The size of the defect predicts that it will not likely close on its own.
 - (D) The risk of incarceration is significant.
 - (E) Repair should be delayed until the child is 4 years old.
10. One week after open repair of a large right scrotal hernia, a 45-year-old male returns complaining of severe pain in his right testicle. The pain has gradually worsened since surgery. On physical exam, the testicle appears to be slightly swollen and very tender to palpation. Doppler study demonstrates no flow within the right testicle with normal flow in the left. Which of the following is true about this condition?
- (A) It is most commonly due to thrombosis of the pampiniform plexus.
 - (B) Urgent exploration of the right testicle is recommended.
 - (C) It is most likely due to transection of the testicular artery.
 - (D) It most likely represents testicular torsion.
 - (E) The testicle will likely remain permanently enlarged.

Answers

1. Answer E
Given leukocytosis, elevated CRP, elevated creatinine, hyponatremia, and the exam findings, there is a very high likelihood that this patient has a necrotizing soft tissue infection (NSTI). After IV fluids, blood cultures, and immediate broad-spectrum IV antibiotics, the next best step is to perform an emergent wide surgical debridement. If the diagnosis of NSTI is uncertain, yet the suspicion is high, surgical exploration is *still indicated*, as this is the gold standard of both diagnosis and treatment. The incision must be taken down to the fascia and muscle, so both can be inspected. When the diagnosis is in question, plain X-rays are useful as they may demonstrate gas in the soft tissue (A). CT scan may also be beneficial for the same reason (B). Duplex scan of leg veins is used to rule out deep venous thrombosis, which can present with leg swelling, but like compartment syndrome, it would not cause the laboratory abnormalities described (C, E).
2. Answer E
Multigravida causes stretching of the abdominal musculature and increases the risk of femoral hernia. Femoral hernias occur in the femoral canal, inferior to the inguinal ligament traversing the empty space medial to the femoral vein (recall the mnemonic "NAVEL" {from lateral to medial/femoral nerve, artery, vein, empty space, lymphatic}) (C). The most common type of hernia in women, and in men, is an indirect inguinal hernia (A). Although femoral hernias appear infrequently (10% of all hernias), they occur more commonly in females and have the highest risk of strangulation (B). Because of the high risk of strangulation, surgical repair of a femoral hernia is indicated once diagnosed, regardless of whether the patient is having symptoms (D).
3. Answer A
The genital branch of the genitofemoral nerve provides sensation to the hemi-scrotum (and labia), as well as the cremaster muscle. The femoral branch of the genitofemoral nerve provides sensation to the proximal medial thigh (B). The ilioinguinal nerve provides sensation to the lower abdomen and medial thigh (C). This nerve is the most commonly injured nerve in *open hernia repair*. The lateral femoral cutaneous nerve provides sensation to the lateral thigh as low as the knee and is the most common nerve injured during *laparoscopic hernia repair* (D). The iliohypogastric nerve supplies the skin overlying the pubis (E).

- ✓ 4. Answer A
Recognizing when to operate is critically important. This patient has small bowel obstruction (SBO) with evidence of ischemic or gangrenous bowel most likely secondary to adhesions from past surgery (e.g., sigmoidectomy). Necrotic bowel generally does not occur in association with SBO unless there is a closed-loop obstruction. A closed-loop obstruction is a particularly dangerous form of bowel obstruction in which a segment of intestine is obstructed both proximally and distally. This is more common in the large bowel as a competent ileocecal valve (present in 70–80% of the population) serves as one point of obstruction. Gas and fluid accumulate within this segment of bowel and cannot escape. This progresses rapidly to strangulation with risk of ischemia, gangrene, and subsequent perforation. Clues to ischemic bowel include the presence of acidosis, fever, leukocytosis, and severe localized pain (unusual for SBO). As such the patient will need exploratory laparotomy, and any bowel that is obviously nonviable needs to be resected. Most patients with SBO (without necrotic bowel) due to adhesions improve with conservative management and do not require surgery. Observation is not appropriate for this patient (B). Upper GI studies would not be indicated since this patient has strong evidence of necrotic bowel and requires urgent surgical intervention (C–D). Abdominal ultrasound is appropriate in the workup for cholelithiasis (E).
- ✓ 5. Answer A
A rising WBC and lactate after debridement are highly suggestive of progression of the NSTI. A second-look operation is often required but in this case would be essential in order to ensure that no additional tissues have become involved since the initial debridement. Amputation may be necessary, but only a second-look operation will indicate whether this is the case (B). CT scan in the postoperative setting would be difficult to interpret due to postsurgical changes (D). With severe sepsis, vasopressors may be necessary, but this would not be the definitive treatment (E). Furthermore, no hemodynamic parameters (blood pressure, central venous pressure) are provided that would indicate that vasopressors are needed. Patients with NSTI should always receive broad antibiotic coverage at initial presentation as it is often due to a polymicrobial infection. However, the cornerstone of management is surgical debridement (C).
- ✓ 6. Answer D
Always consider a nonmechanical postoperative ileus in patients that have had a recent surgery. This occurs in up to 50% of patients that have undergone abdominal surgery. Although the exact cause has not been elucidated, it most likely involves impaired peristalsis of intestinal contents. Inflammatory mediators (e.g., recent surgery) and opioid analgesics are thought to contribute to the development of postoperative ileus. Initial management should begin with changing pain medication to a non-opiate analgesic. The only other options for analgesia are NSAIDs or acetaminophen. Encouraging ambulation is an important element of recovery in all postsurgical patients but is not as important as discontinuing opiates in the management of postoperative ileus (A). If the patient's symptoms worsen (e.g., emesis), bowel decompression with a nasogastric tube should be considered (B). Neostigmine is used in patients with pseudo-obstruction (Ogilvie's syndrome) (C). Returning to the OR for exploration is inappropriate for postoperative ileus (E).
- ✓ 7. Answer D
A retroperitoneal organ (such as colon) protruding into a hernia sac describes a sliding hernia (A). With a Richter's hernia, only part of the circumference of the bowel wall is trapped within the hernia sac. That segment of bowel is prone to incarceration and strangulation but does so without associated symptoms, signs, or radiologic evidence of SBO (C). Therefore, it may easily mislead clinicians into thinking that the hernia is not incarcerated (B). Manual reduction of hernias (including Richter's) should not be attempted if strangulation is suspected as dead bowel will be reduced into the peritoneum. Strangulation should be suspected in the presence of fever, leukocytosis, acido-

sis, severe pain, or marked erythema overlying the skin of the hernia. It is often difficult to palpate a Richter's hernia, and it should be reduced in the operating room (E).

✓ 8. Answer A

This patient has evidence (on history, physical, and radiologic imaging) of a SBO that is most likely secondary to adhesions from prior surgery (abdominal scar). SBO from adhesions can present many years after surgery. The initial management of SBO includes placing the patient NPO, aggressive intravenous fluid resuscitation (the patient is tachycardic and likely very dehydrated), and nasogastric tube placement. Aside from the salutatory effect of gastric decompression on the distended bowel, patients with SBO are at risk of aspiration. Once the patient has been adequately resuscitated, CT scan with oral contrast is recommended as it is useful in confirming the diagnosis of SBO, determining if the SBO is partial or complete, and ruling out other diagnosis (E). Most patients with SBO due to adhesions improve with these maneuvers and do not require surgery. Operative management with laparotomy and lysis of adhesions should be considered in the following conditions: if the patient demonstrates evidence of clinical deterioration as manifest by increasing pain, tenderness, fever, leukocytosis, or acidosis (C). Operative management can be achieved either via open laparotomy or laparoscopy (B). Evidence of a *complete SBO* is a relative indication for surgery, but recent studies suggest that some of these patients resolve with non-operative management as well. Intravenous erythromycin acts as a prokinetic agent and has some utility for gastroparesis, but not for SBO (D). In cases where a mechanical obstruction is suspected, prokinetic agents should be avoided.

✓ 9. Answer E

This patient has an umbilical hernia, which is a common finding in newborns. It is recommended that repair be delayed until after the child is 4 years old, unless the defect is larger than 2 cm, the defect is growing, or there is evidence of strangulation (A). Umbilical hernias are not associated with the VACTERL (vertebral, anal, cardiac, tracheoesophageal fistula, renal, limb) complex of anomalies (B). Defects smaller than 2 cm will likely close spontaneously (C). It is very rare for umbilical hernias in children to incarcerate (D).

✓ 10. Answer A

This patient likely has ischemic orchitis secondary to damage or thrombosis of the pampiniform plexus. This is most likely to occur in patients with large or densely adhered hernia sacs. The condition is usually self-limited, so urgent exploration is not indicated (B, E). Ischemic orchitis is more commonly caused by injury to the pampiniform plexus than to the testicular artery (C). Testicular torsion is less likely than a vascular injury in this case, and although it will also have a decreased or absent Doppler signal, the pain occurs suddenly (D).

Breast and Skin

Danielle M. Hari

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Abnormal Screening Mammogram

Areg Grigorian, Christian de Virgilio, and Danielle M. Hari

Case Study

A 40-year-old woman sees her doctor for an annual physical exam. She is healthy and does not take any medications. She has a family history of breast cancer. Her physical examination is normal with no palpable breast masses. Her doctor recommends that she get a screening mammography as part of her routine health maintenance screening, which she agrees to do. A week later, she gets a call from her doctor to inform her that the mammogram is abnormal (BI-RADS 4). Her left breast was found to have multiple clusters of fine linear microcalcifications, with the largest cluster measuring 2 mm in diameter.

Diagnosis

What Is the Differential Diagnosis for an Abnormal Mammogram in the Absence of a Palpable Breast Mass?

Table 5.1

Select benign calcifications	
<i>Skin calcifications</i>	May be secondary to dermatitis or hygiene products (e.g., deodorants, ointments)
<i>Vascular calcifications</i>	Linear or parallel tracks; may be associated with underlying vascular disease
<i>Coarse or "popcorn" like</i>	Dystrophic in origin and usually associated with underlying fibroadenoma
<i>Round and punctate calcifications</i>	Associated with fibrocystic changes of the breast, adenosis, and skin calcifications
<i>Eggshell or rim calcifications</i>	Appear to be deposited on the surface of a sphere; can be seen in fat necrosis or fibrocystic changes of the breast
<i>Dystrophic calcifications</i>	Coarse, irregular shaped; seen in irradiated breast or following trauma
Suspicious calcifications	
<i>Amorphous calcifications</i>	Without a clearly defined shape or form; small and hazy appearance
<i>Coarse heterogeneous</i>	Irregular, conspicuous calcifications typically larger than 0.5 mm; associated with benign (e.g., fibroadenoma, fibrosis) and malignant conditions (e.g., DCIS)
High probability of malignancy	
<i>Fine pleomorphic</i>	Classified as BI-RADS 5; typically associated with DCIS
<i>Fine linear/linear branching</i>	Represent casts of the ducts ("casting" type) in which they lie; often associated with comedo subtype of intraductal carcinoma, typically high grade or poorly differentiated

DCIS ductal carcinoma in situ

What Is the Most Likely Diagnosis?

Fine, linear calcifications on mammogram are highly suggestive of malignancy. Such calcifications form in areas of necrosis and in a linear pattern. This is likely from dead cancer cells lining the ducts that outgrow their blood supply. Thus, the most likely diagnosis is malignancy. Since the lesion is small and there is no palpable mass, it most likely represents ductal carcinoma in-situ (DCIS) as opposed to invasive ductal carcinoma. In addition, she has a family history of breast cancer which increases her risk.

Screening

What Are the Recommendations for Breast Cancer Screening?

The age and frequency of screening is controversial. Some cancer societies recommend screening at age 40, whereas others recommend screening starting at age 50 in normal-risk patients. Similarly, the ideal interval is controversial, with some recommending annual screenings and others every other year. It is unclear at what age screening should stop. The US Preventive Services Task Force (USPSTF) recommends that screening end at age 74. Others recommend "continuing for as long as a woman is in good health" (American Cancer Society). In addition to mammography, the American Cancer Society recommends clinical breast examination every 3 years from age 20 to 39 and annually thereafter. The USPSTF cites insufficient evidence to recommend clinical breast examination. Self-breast examination is generally not recommended.

Watch Out

If the surgery shelf exam asks about screening for breast cancer, the likely answer is starting at age 40 and continuing annually.

What Are the Risks of Mammography?

Mammograms utilize small doses of radiation, which, over time, can place patients at an increased risk for cancer. However, for most women over 50, the benefits of regular mammograms outweigh any potential radiation risks. Additionally, mammograms can miss up to 20% of cancers, particularly small ones, and those that are in areas that are difficult to view. On the other end of the spectrum, it may detect cancers that would have otherwise never led to symptoms, subjecting the patient to the adverse effects of intervention or additional testing (e.g., biopsy). Lastly, mammograms are not always accurate. Mammographic findings are heavily dependent on the technique used in attaining the images, the experience of the radiologist evaluating the images, and the breast density of the patient.

Why Is Mammography Not Useful in Young Women (<30 Years Old)?

Younger women tend to have denser breast tissue due to a decreased level of fat. Dense breasts make it difficult to detect abnormal calcifications or masses.

History and Physical

What Is the Gail Risk Model?

The most commonly implemented risk assessment model is the Breast Cancer Risk Assessment Tool (BCRAT), also known as the Gail model. The BCRAT is a mathematical model used to calculate the risk of developing breast cancer. The model considers factors such as age, age at menarche, reproductive history, family history in first-degree relatives, and prior biopsies. One disadvantage of the model is that it can underestimate breast cancer risk in women with a strong family history of breast or ovarian cancer that does not involve first-degree relatives; if this is the case, alternative risk models should be implemented.

Watch Out

Age of menopause is *not* a factor in the Gail model. This is important as it allows this tool to be used in all women including those that are postmenopausal.

Pathophysiology

What Is One Characteristic of Mammographic Calcifications that Helps Differentiate Between Benign and Malignant Conditions?

Larger calcifications (macrocalcifications) are almost always benign, while smaller calcifications (microcalcifications) are more frequently seen in patients with breast cancer.

What Are the Primary Features of Ductal Carcinoma In Situ?

DCIS is characterized by malignant epithelial cells within the mammary ductal system, without invasion into the surrounding stroma. DCIS has several histological patterns, including comedo with prominent central necrosis, cribriform with back-to-back glands, and papillary. Comedo-type DCIS is typically high grade and associated with a worse prognosis. DCIS is often multifocal and can be associated with a concurrent invasive carcinoma. DCIS lesions have a high risk of subsequent invasive carcinoma at the site of the DCIS.

What Are the Primary Features of Lobular Carcinoma In Situ?

Lobular carcinoma in situ (LCIS) is characterized by malignant epithelial cells that arise from the lobules and terminal ducts of the breast. Unlike DCIS, it is *not* a premalignant lesion but rather is a marker for the development of future ipsilateral as well as contralateral invasive breast cancer (ductal or lobular) (■ Table 5.2). It is almost always incidentally found on a breast biopsy that is performed for some other reason. LCIS itself is not thought to progress to invasive lobular carcinoma, so there is no role for resecting it to attain clear margins. However, *excisional biopsy* is still recommended to rule out concurrent invasive cancer. Two forms of LCIS have been associated with microcalcifications on mammography: classic form with small uniform cells and the pleomorphic form with larger cells. The relative risk of developing an invasive cancer in women with LCIS is approximately 2× higher compared to women without LCIS.

■ **Table 5.2** Ductal carcinoma in situ (DCIS) versus lobular carcinoma in situ (LCIS)

	DCIS	LCIS
<i>Presentation</i>	Incidental microcalcifications on mammography	Incidental finding on histopathology
<i>Location</i>	Ducts, multifocal	Lobules
<i>Pattern</i>	Comedo (prominent necrosis in the center of the involved spaces), micropapillary, cribriform (back-to-back glands)	Solid
<i>Axillary metastasis</i>	Present in up to 10% of patients	Usually absent
<i>Incidence of concurrent invasive carcinoma</i>	High	Low
<i>Risk of subsequent invasive carcinoma</i>	High	Low
<i>Treatment</i>	Excision to negative margin; consider sentinel lymph node biopsy in select group	If found on excisional biopsy, then close observation; if found on core needle biopsy, excise area to rule out adjacent cancer; possibly tamoxifen

■ Table 5.3 BI-RADS

BI-RADS category	Interpretation
0	Incomplete assessment; needs additional imaging and/or old imaging comparison
1	Negative; continue screening based on current screening guidelines
2	Benign findings; continue screening based on current screening guidelines
3	Probably benign; recommend shorter interval follow-up (e.g., diagnostic mammography and/or ultrasound at 6-month intervals for 1 year)
4	Suspicious abnormalities; biopsy should be considered
5	Highly suggestive of malignancy; biopsy recommended

How Does Breast Cancer Metastasize to the Spine?

Batson plexus is a network of valveless veins that are thought to be the route for metastasis of breast cancer to the spine.

Workup

How Are Mammograms Used in Staging Breast Lesions?

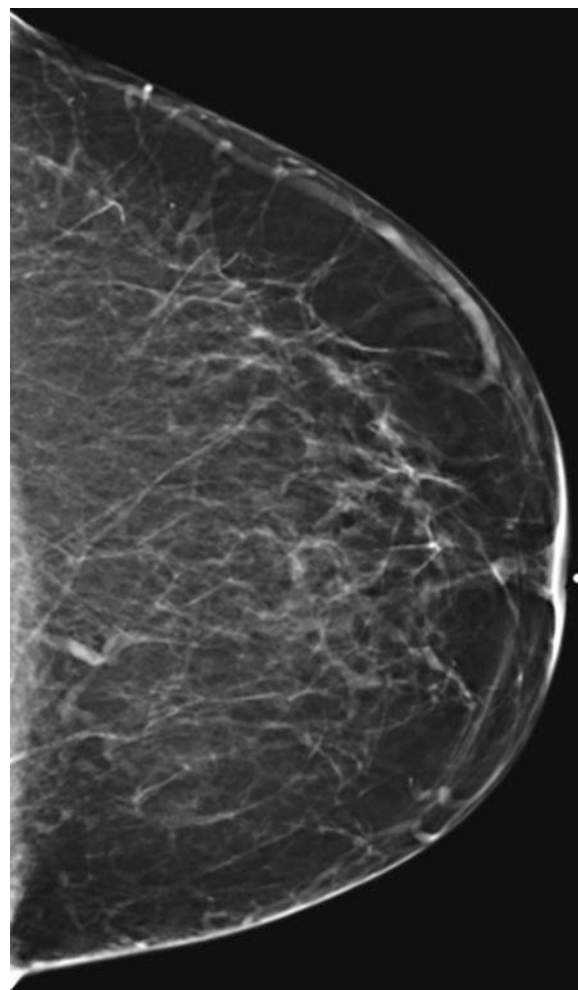
Mammogram abnormalities include masses, microcalcifications, and asymmetry. The radiologist summarizes the mammographic findings using the American College of Radiology's Breast Imaging Reporting and Data System (BI-RADS) final assessment (■ Table 5.3), which standardizes the reporting of mammographic findings and indicates the relative likelihood of a normal, benign, or malignant diagnosis. It is important to note that the BI-RADS category only refers to the imaging findings and does not take clinical information into account (■ Figs. 5.1 and 5.2).

Watch Out

Clinically suspicious masses in a patient with a low BI-RADS score *still* require biopsy. Similarly, BI-RADS-5 lesions found to be benign on core needle biopsy are considered "benign-discordant" and should be surgically excised.

What Is the Next Step in Management for the Above Patient?

An abnormal mammogram, in particular a BI-RADS 4 or BI-RADS 5, requires further work-up. This could include addi-



■ Fig. 5.1 Normal screening mammogram, craniocaudal (CC) view

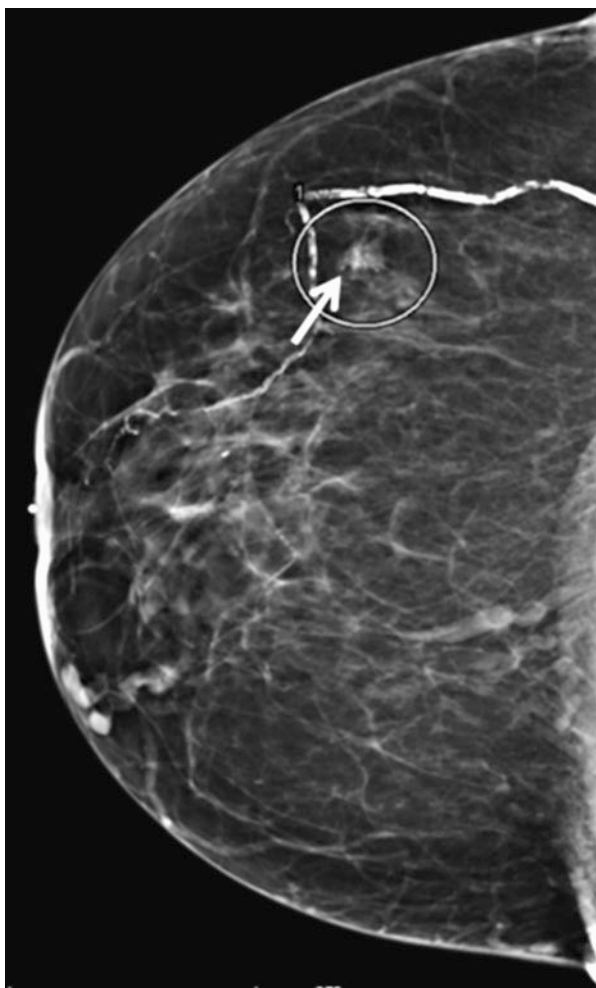
tional diagnostic mammographic views, ultrasonography, and stereotactic core needle biopsy.

What Is a Stereotactic Core Needle Biopsy?

A stereotactic core needle biopsy is performed on lesions that are *not palpable* and only visible on mammography. The lesion is biopsied with a hollow needle using image guidance (e.g. X-ray) by a radiologist.

How Does One Interpret the Results of a Stereotactic Core Needle Biopsy?

The biopsy may come back benign or malignant. If it is benign, the radiologist decides if the pathology results are concordant (consistent) with the mammographic lesion or discordant. If it is benign and concordant, then no further treatment is needed. If it is discordant (biopsy benign, but not consistent with the concerning mammographic findings) further excision is required.



■ **Fig. 5.2** Abnormal screening mammogram (CC view) showing 1 cm foci of microcalcifications in the upper outer quadrant BI-RADS (category 0)

What Is the Next Step if the Stereotactic Biopsy Is Discordant?

The lesion needs to be removed via an excisional biopsy. However, since the lesion is not palpable, this needs to be done via a procedure known as a wire localization. This involves coordination between the radiologist and the surgeon. The radiologist marks the lesion by inserting a wire through the skin, directly into the area of suspicious calcification under radiologic guidance. The tip of the wire has a hook to keep it in place. The patient is then taken to the operating room, where the surgeon makes an incision over the protruding wire and excises a core of tissue around the tip of the wire. An X-ray image of the specimen is obtained to confirm that all of the suspicious calcifications have been removed. It is then sent to pathology. If the tumor is benign, no further treatment is needed. If the

lesion is malignant, a cancer surgery needs to be performed (lumpectomy/radiation OR mastectomy).

What Other Findings on Core Needle Biopsy Require Excisional Biopsy?

Certain findings on core needle biopsy have higher risk for concurrent malignancy, and so a wire-localized excisional biopsy is recommended. These include LCIS, atypical ductal/lobular hyperplasia, flat epithelial atypia, and radial scar. The reason is that a malignancy can be discovered in the vicinity of these lesions. However, since these lesions themselves do not lead to progression to cancer, the excisional biopsy does not require negative margins.

What Constitutes Positive Margins on a Malignant Specimen?

After excision, the margins of the specimen are inked, and the pathologist must confirm that there is *no tumor on the ink*. If there is tumor on the ink, it is considered a positive margin.

Management

What Is the Next Step if the Stereotactic Needle Biopsy Demonstrates DCIS?

DCIS, if left unresected, will often progress to invasive ductal cancer. Thus, the mainstay of DCIS treatment is complete excision via lumpectomy to negative margins or a mastectomy. If after lumpectomy the margins are positive, a re-excision or mastectomy is indicated.

What Is the Next Step if the Stereotactic Biopsy Demonstrates LCIS?

If LCIS is found on core needle biopsy, one would perform a wire localized excisional biopsy (not a lumpectomy). This is done to rule out the presence of adjacent cancers that are sometimes found. This excision differs from a lumpectomy in that a smaller area of breast tissue is removed to get a better sample of the area. Unlike DCIS which leads to an invasive cancer directly in the lesion, the LCIS lesion does not directly lead to invasive cancer. Therefore, a negative margin is not necessary. If the excisional biopsy only shows LCIS, then no further surgery is recommended. LCIS is a risk factor for developing invasive cancer in either breast (any type, not just lobular).

Watch Out

Pleomorphic subtype of LCIS is considered an aggressive subtype. As such pleomorphic LCIS needs an excisional biopsy with negative margins but does not require additional treatment (such as radiation) unless an invasive component is found.

5

What Are the Treatment Options for LCIS?

Since LCIS is a marker for breast cancer in either breast, treatment most commonly involves carefully monitoring the patient for the development of invasive cancer with serial mammograms and physical exam. The National Surgical Adjuvant Breast and Bowel Project - Prevention-1 (NSABP-P-1) trial demonstrated that the use of tamoxifen in women with LCIS decreased the risk of developing invasive breast cancer by 50%. Bilateral prophylactic mastectomy is sometimes considered as an alternative for high-risk women and this provides a 90% risk reduction.

Watch Out

Tamoxifen should not be used in pregnant women due to its teratogenicity, or in lactating women as it may suppress milk production.

What if the Stereotactic Biopsy Shows Invasive Ductal Carcinoma?

The two basic options are breast-conserving therapy (BCT), which consists of a lumpectomy (partial mastectomy) and radiation therapy (to decrease the risk of local recurrence) versus simple/total mastectomy. For invasive breast cancers a sentinel lymph node biopsy (SLNB) is also performed during breast surgery.

Can You Get Lymph Node Metastasis with DCIS?

DCIS is, by definition, confined within the mammary duct and has not breached the basement membrane allowing it to enter the surrounding tissue or the lymph system. However, when DCIS is multifocal, comedo subtype, or high grade, it may have an invasive component that is missed and subsequently result in lymph node metastasis. This occurs in a small number of DCIS cases. As such, SLNB is generally not recommended for DCIS. However, for certain high-risk lesions such as extensive microcalcifications on mammogram >5 cm, or DCIS associated with a palpable mass, SLNB should be performed. It is also recommended if the patient chooses a mastectomy for treatment.

Mastitis that Does Not Resolve with Antibiotics

Mastitis most often occurs in lactating patients and presents with a warm, erythematous, and tender breast. The most common organism is *Staphylococcus aureus*. The treatment is antibiotics covering *S. aureus*, continued breast-feeding (this does not pose a risk to the infant), and lactation consultation. Women that are not lactating can also develop mastitis when there is an obstruction or pseudo-obstruction of the lactiferous duct. Risk factors include trauma to the nipple (e.g., scarring from nipple piercing), granulomatous disease of the breast, smoking (leads to keratinizing squamous metaplasia), and hidradenitis. Alcohol has not been demonstrated to be associated with mastitis or breast abscesses. In a woman treated for mastitis that does not resolve or recurs, a mammography should be performed.

Areas of Controversy**Does Screening Mammography Actually Reduce Mortality from Breast Cancer?**

A recent (though highly controversial) study suggests that screening mammography may not be effective in reducing mortality from breast cancer. A 25-year longitudinal randomized screening trial study showed that mortality rates were similar in women that received an annual mammogram for 5 years to those that did not. These controversial findings may reflect older mammogram techniques, whereas newer 3-D mammography is much better.

Prophylactic Bilateral Mastectomy

Women with strong family histories of breast cancer, genetic mutations (BRCA-1 or BRCA-2), radiation therapy to the chest before age 30, or conditions that place them at increased risk for developing invasive cancer may consider prophylactic surgery to remove both breasts. LCIS is a marker for increased risk of developing cancer in either breast. Patients with LCIS and a family history of breast cancer could be considered suitable candidates for prophylactic bilateral mastectomy. Patients without a family history may not benefit from such aggressive intervention because of such a low risk of progression to cancer.

Summary of Essentials**Diagnosis**

- DCIS and LCIS do not typically present as palpable masses.
- Benign calcifications: skin, vascular, popcorn-like, plasma cell mastitis, lucent-centered, eggshell or rim, milk of calcium, suture, or dystrophic.
- Suspicious calcifications: fine, linear, branching, and pleomorphic microcalcifications.

Screening

- Age and frequency of screening are controversial.
- Some cancer societies recommend screening in normal-risk women starting at age 40, while others recommend starting at age 50.
- ACS recommends clinical breast examination every 3 years from age 20 to 39 and annually thereafter.

History and Physical

- Gail risk model to help calculate risk of developing breast cancer

Etiology/Pathophysiology

- Macrocalcifications are almost always benign, while microcalcifications are more concerning for cancer.
- DCIS can progress to invasive cancer if left unresected.
 - Can be multifocal
 - Can be associated with a concurrent invasive carcinoma
- LCIS is only a marker for the development of future ipsilateral as well as contralateral invasive breast cancer (either lobular or ductal).

Workup

- BI-RADS (0–5) is a standardized summary of mammographic findings.
- BI-RADS 3 is probably benign (2% chance of cancer); BI-RADS 4 is suspicious (15–30%).

- Stereotactic biopsy for BI-RADS 4 or BI-RADS 5.
- Wire localized excisional biopsy for discordant findings.

Management

- DCIS: lumpectomy to negative margin or mastectomy.
- LCIS (found on excisional biopsy): depends on risk factors; low risk can be treated with observation or tamoxifen, while high risk can be offered prophylactic bilateral mastectomy.
- LCIS found on core biopsy requires excisional biopsy to rule out adjacent or associated ductal or lobular cancer.

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New Palpable Mass in the Right Breast

Areg Grigorian, Christian de Virgilio, and Danielle M. Hari

Case Study

A 55-year-old postmenopausal female presents with a new mass in her right breast. She states that the mass has been there for about 3 months and has slowly grown in size. She first noticed it when she was taking a shower. The mass is not painful. She reports no nipple discharge, no nipple inversion, and no skin changes. She had her first menstrual period at age 11. Her only pregnancy was at age 35. Her mother and sister both had breast cancer. On physical examination, she has a 2 cm palpable, hard, ill-defined, immobile, non-tender mass in the upper outer quadrant of her right breast. There is no palpable axillary or supraclavicular adenopathy.

6

Diagnosis

What Benign Conditions Are in the Differential Diagnosis of a Palpable Breast Mass?

Table 6.1

Condition	History and physical	Features
<i>Fibrocystic change</i>	Vague irregularity of breast tissue (lumpy breast), often in upper quadrants, cysts have a blue-dome appearance on exam	Most common <i>overall breast mass</i> in women; found in 60–90% of breasts during routine autopsy; normal variant of premenopausal breast
<i>Fibroadenoma</i>	Well-circumscribed, mobile, rubbery, encapsulated mass	Most common <i>benign tumor</i> ; typically affects women < 30 years; most common tumor in premenopausal women, estrogen sensitive causing it to grow during pregnancy (most are identified during pregnancy)
<i>Intraductal papilloma</i>	Classically presents as unilateral bloody nipple discharge in premenopausal women	Most common cause of bloody nipple discharge in women aged 20–40 years; usually do not show up on mammogram; papilloma is lined by epithelial (luminal) and myoepithelial cells in contrast to cancer cells which are only lined by luminal cells
<i>Fat necrosis</i>	Following trauma or recent breast surgery; feels hard like cancer, can cause skin dimpling, may be accompanied by pain	Abnormal calcification on mammogram secondary to saponification
<i>Abscess</i>	Painful mass typically in lactating breast, erythematous and warm, fevers, purulent drainage from mass or nipple discharge	Postpartum mastitis: localized cellulitis caused by bacterial invasion through an irritated or fissured nipple
<i>Galactocele</i>	Painful or painless aseptic mass in lactating breast that is not warm or erythematous	Typically occurs on cessation of lactation; can be managed by massaging the breast or aspiration
<i>Mondor's disease</i>	Tender lump, sudden onset	Thrombosis of a superficial chest wall vein, warm compress, NSAIDs

What Malignant Lesions Are in the Differential Diagnosis of a Palpable Breast Mass?

Table 6.2

Type	History and physical	Features	Prognosis
<i>Ductal carcinoma in situ (DCIS)</i>	Does <i>not</i> usually present as a palpable mass	Malignant cells in ducts with no invasion of the basement membrane; incidental microcalcifications on mammogram; if presents as a mass, higher chance of concurrent invasive carcinoma; considered premalignant	Majority do well
<i>Lobular carcinoma in situ (LCIS)</i>	Does <i>not</i> usually present as a palpable mass	Malignant epithelial cells that arise from the lobules and terminal ducts of the breast; <i>not</i> premalignant	Majority do well
<i>Invasive ductal carcinoma</i>	Firm, immobile, discrete mass, nipple retraction, painless	Malignant cells in ducts with stromal invasion and microcalcifications, most common form of invasive breast cancer	Dependent on stage
<i>Invasive lobular carcinoma</i>	Firm, immobile, discrete mass, nipple retraction, painless, frequently bilateral	Malignant cells in breast lobules with insidious infiltration, more responsive to hormonal therapy; higher risk of bilateral disease	Dependent on stage
<i>Mucinous carcinoma</i>	Gelatinous well-circumscribed mass	Well-circumscribed mass, slow growth, more common in elderly	Poor
<i>Inflammatory carcinoma</i>	Inflamed, tender, warm, erythematous breast, peau d'orange	Carcinoma that has infiltrated the subdermal lymphatics, rapid progression, angioinvasive behavior	Poor
<i>Phyllodes tumor</i>	Feels like giant fibroadenoma, fast growing, firm, rubbery, and large	Benign or malignant, hard to diagnose with needle biopsy, wide local excision, locally recurrent, doesn't metastasize to lymph nodes, can behave like sarcoma	Dependent on malignant

What Is the Most Likely Diagnosis for This Patient?

Invasive breast cancer is the most likely diagnosis in a postmenopausal woman with a new palpable breast mass that is non-tender, hard, ill-defined, immobile, and in the upper outer quadrant. In addition, she has other risk factors for breast cancer including family history in a first-degree relative and early menarche. Most women who detect breast masses do so in the shower or after trauma to the chest, which brings attention to a palpable mass.

History and Physical

What Features on Physical Examination Are Suggestive of Breast Cancer?

Physical exam findings of benign breast masses can be hard to differentiate from cancer, since normal variants of breast tissue may feel nodular. A careful inspection for asymmetry, skin changes, and nipple discharge (or crusting) should be done for each patient reporting a newly found breast mass. A bimanual examination of the breasts should then be

performed with the patient in a supine position, with the ipsilateral arm raised above her head, palpating for any obvious masses. A single dominant lesion that is hard and immobile, with irregular borders, is suspicious for breast cancer. The cervical, supraclavicular, infraclavicular, and axillary nodes should also be examined. Enlarged, firm, immobile, and/or matted lymph nodes suggest disseminated cancer.

What Are the Risk Factors for Breast Cancer?

The most important risk factors for breast cancer are female gender, increasing age, and a family history of premenopausal breast cancer. In particular, a family history of breast cancer in males or premenopausal women, bilateral breast cancer, a history of ovarian cancer, and multiple relatives with cancer should prompt investigation for the presence of a gene mutation. The majority of inherited breast cancers are associated with BRCA1 or BRCA2 gene mutations. Other important risk factors associated with a slightly higher risk of developing breast cancer include diethylstilbestrol (DES) exposure, early menarche, nulliparity or childbirth after age 30, and/or late menopause. Table 6.3 shows the relative risk of developing breast cancer for certain risk factors.

Table 6.3 Relative risk (RR) for breast cancer

Low (<2 RR)	Moderate (2–4 RR)	High risk (>4 RR)
Age at menarche < 12	Age at first birth > 30	BRCA1/BRCA2 mutation
Age at menopause > 55	Mother or sister with breast cancer	Age > 70
Nulliparity	Previous breast cancer	
Obesity	Radiation exposure	
Hormone replacement therapy		

Watch Out

Increased lifetime exposure to *estrogen* is a common theme shared by most of the risk factors for breast cancer.

What Are the Different Types of Nipple Discharge and What Is the Differential Diagnosis for Each?

Nipple discharge is categorized as normal milk production (lactation), physiologic nipple discharge, or pathologic nipple discharge. Benign nipple discharge tends to be clear, bilateral, and multiductal. Physiologic discharge can be related to post-lactation (up to 2 years following birth), fluctuating hormone levels (puberty and menopause), or nipple stimulation. Pathologic nipple discharge can be due to medical conditions such as prolactinoma, hypothyroidism (thyroid-releasing hormone stimulates prolactin), Cushing's disease, or medications (e.g., antipsychotics, cimetidine, spironolactone). The most common cause of pathologic nipple discharge (unilateral, bloody) is a papilloma, which is a benign tumor growing from the lining of the breast duct. Nevertheless, malignancy can be found in up to 15% of patients that present with nipple discharge. The likelihood of cancer is higher if the discharge is bloody (versus non-bloody), spontaneous, unilateral, uniductal, and associated with a breast mass or if it occurs in women older than 40 years.

Pathology/Pathophysiology

What Histologic Features of Fibrocystic Changes Are Associated with Increased Risk for Cancer?

Most cases of fibrocystic-related changes are benign, but certain features place patients at an increased risk for invasive carcinoma in both breasts. Whereas apocrine metaplasia has no increased risk for cancer, ductal hyperplasia or sclerosing

adenosis doubles the risk of cancer development. Atypical hyperplasia has the highest risk for cancer.

What Is the Pathophysiology of “Peau d’Orange”?

Peau d'orange is a French term meaning “skin like an orange peel.” It is caused by tumor cells invading local lymphatics, leading to lymphedema of the skin, expanding the interfollicular dermis and producing characteristic dimples which resemble the texture and appearance of orange peels. When deeper subcutaneous layers are involved, it can also cause pitting. This finding is most commonly seen in inflammatory carcinoma. A full-thickness, punch biopsy of the dermis is essential for definitive diagnosis and will demonstrate cancer cells. This is vital, as inflammatory breast cancer is managed differently (see below).

What Is the Pathophysiology of Nipple Retraction?

The suspensory ligaments of the breasts are called *Cooper's ligaments*. When a breast tumor infiltrates these ligaments, it can retract the skin, often at or around the nipples.

Workup

What Is the Triple Test for a New Breast Mass?

The “triple test” is a clinical tool that should be applied to all newly detected breast masses. This includes careful physical examination, imaging, and tissue sampling, with each test classified as benign (1 point), suspicious (2 points), or malignant (3 points). A range from 3 to 9 can help stratify patients into groups that are likely benign to a high likelihood of malignancy.

How Does the Age of the Patient Affect the Workup of a New, Palpable Breast Mass?

The recommended imaging depends on the age of the patient. The breasts of younger women consist of dense, fibrous tissue, and as such, mammography is not as useful in detecting abnormalities. In addition, most breast masses in women under 30 are benign, so it is best to avoid unnecessary radiation. Therefore, ultrasound is the first line of imaging in a woman who is less than 30 years old with focal breast findings, as well as those who are pregnant. Ultrasound can differentiate a cystic mass from a solid mass and can be used for needle-guided aspiration if indicated. If the mass is a simple cyst, it can be observed. If the cyst is painful or enlarging, it should be aspirated. If the fluid is bloody, it should be sent for cytology. If the mass is solid, a biopsy should be performed.

The diagnostic procedure of choice is core needle biopsy rather than surgical biopsy. Breast magnetic resonance imaging (MRI) is not indicated for the workup of a new breast mass but is reserved for diagnostic dilemmas. Note that breast MRI has a high false-positive rate.

What Imaging Is Recommended for Working Up a New Breast Mass in Women Over 30?

A diagnostic mammogram should be the first test ordered in a woman over the age of 30 with a new breast mass to better characterize the mass, identify other non-palpable lesions in the affected breast, as well as examine the contralateral breast. Certain mammographic features such as asymmetry, clustered pleomorphic calcification, increasing density, or a new mass with irregular borders or spiculation are suggestive of malignancy. Once a mass is identified, a core needle biopsy (ultrasound-guided, if necessary) should be performed to exclude cancer, regardless of mammogram results (■ Fig. 6.1).

Watch Out

Always proceed with a tissue biopsy for suspicious masses, even if the mammogram is normal.

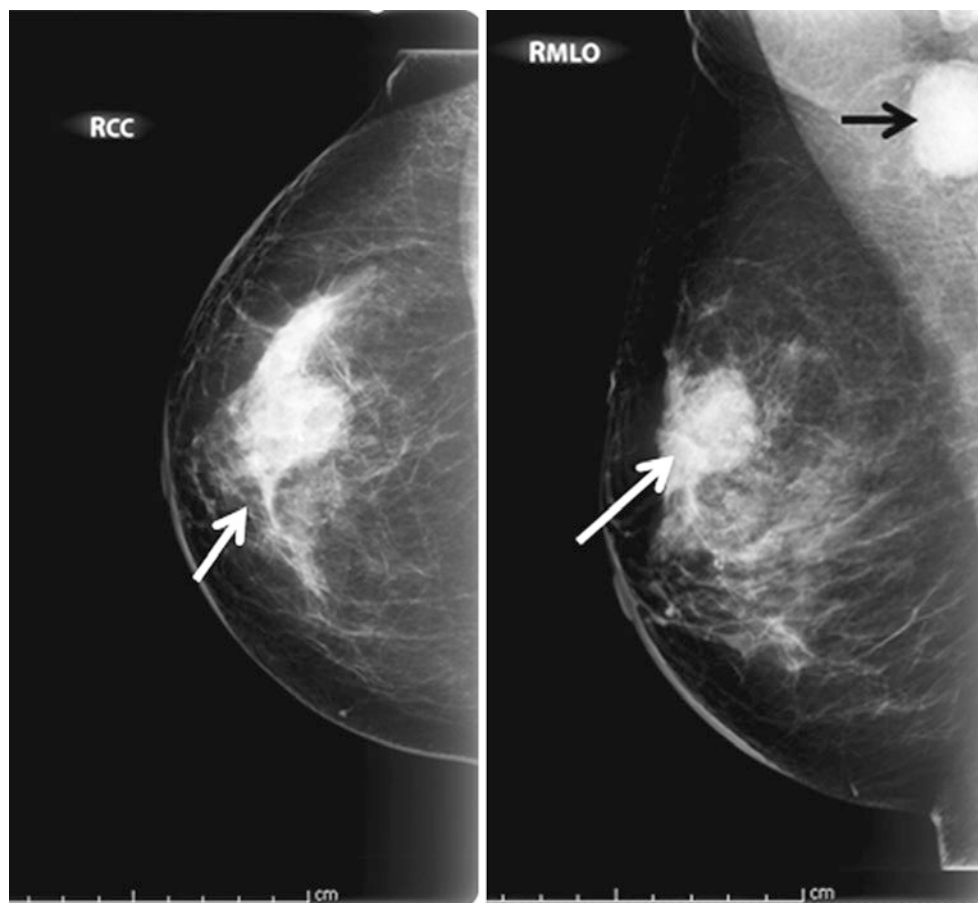
What Metastatic Workup Is Recommended Following a Diagnosis of Breast Cancer?

For clinically early-stage breast cancer, an extensive metastatic workup is not needed. Laboratory tests are obtained only as indicated by symptoms or signs. These studies may include liver chemistries for liver metastasis, or alkaline phosphatase for bone metastasis. A chest X-ray may be obtained as indicated by symptoms to determine the presence of pulmonary metastasis. Routine abdominal and chest CT are not recommended (unless symptomatic or laboratory values or plain chest X-ray is abnormal). Similarly, bone scintigraphy is only obtained if driven by abnormal lab values or the presence of suspicious bone pain. Likewise, the use of brain CT or MRI is symptom-driven (new onset headaches, vision changes, or seizures). PET scan is also not routinely ordered. For those who on physical exam have a clinically advanced breast cancer (Stage III), a more extensive metastatic workup is recommended, including CT of the chest, abdomen, and pelvis, as well as a bone scan.

How Is Breast Cancer Staged Clinically?

The most commonly used staging system is the one described by the American Joint Committee on Cancer (AJCC). *T* (tumor) describes the size of the tumor and/or its depth of invasion. *N* (node) describes spread to regional lymph nodes. *M* (metastasis) indicates if the tumor has metastasized remotely.

■ **Fig. 6.1** Diagnostic mammogram with craniocaudal (CC) view (left) and mediolateral oblique (MLO) view (right). White arrows: mass suspicious for malignancy. Black arrow: enlarged axillary lymph node suspicious for malignant involvement



What Are the Different Tumor Markers for Breast Cancer and How Are They Utilized?

Though tumor markers for breast cancer exist (CA-15-3, CA 27.29, and CEA), they are not used routinely as not all patients with breast cancer have elevated levels. Additionally, these tumor markers have poor sensitivity and specificity making them poor choices for screening tools.

Watch Out

CEA levels can be elevated with benign conditions such as smoking, pancreatitis, liver cirrhosis, and inflammatory bowel disease.

What Is a Triple-Negative Breast Cancer?

This refers to breast cancer that is negative for estrogen (ER), progesterone (PR), and human epidermal growth factor-2 (HER-2) receptors. The fact that these breast cancers do not express these receptors makes them more difficult to treat with conventional therapy. Tumors that express ER/PR receptors are favorable because it allows for the option to employ hormonal drugs as adjuvant therapy to treat breast cancer. HER-2 is a protein that is found in approximately 20% of breast cancer, and anti-HER-2 therapy can help stop proliferation of cancer cells. However, HER-2-positive cancers tend to be more aggressive, and so even with targeted therapy, breast cancer that is HER-2 positive is considered to have worse prognosis. Prognosis for triple-negative breast cancer is typically even worse, requiring more aggressive therapy.

Watch Out

Having ER+/PR+ breast cancer portends a better prognosis than ER+/PR- breast cancer.

What Breast Cancer Subtype Do Patients with BRCA Develop?

Triple-negative tumors typically are the most common subtype in BRCA-1 carriers, demonstrate high histological grade, occur at a younger age (<40 years), and are found more commonly in black women.

What Are the Unique Features of Invasive Lobular Carcinoma?

Invasive lobular carcinoma is typically hormone receptor positive and occurs more commonly in *premenopausal*

women. The growth pattern is linear making it difficult to visualize on mammogram and ultrasound.

Management

What Surgical Options Are Available for Patients with Early (Stage I and II) Breast Cancers?

The two basic options are breast-conserving therapy (BCT), which consists of a lumpectomy (partial mastectomy) and radiation therapy (to decrease the risk of local recurrence), and simple/total mastectomy. For invasive breast cancers or some patients with DCIS without palpable lymphadenopathy, a sentinel lymph node biopsy (SLNB) is also performed during breast surgery. BCT is typically reserved for Stage I and II cancers. Studies have shown that BCT leads to survival rates that are equivalent to that of simple mastectomy while providing a more cosmetically appealing option for women. Following simple mastectomy, radiation therapy to the chest wall is not necessary in the majority of patients.

Watch Out

High-risk features of DCIS include comedo-type, high-grade, >5 cm, palpable, and multifocal lesions.

What Is the Premise Behind SLNB?

A sentinel lymph node is the hypothetical first node or group of nodes from which the lymphatics of the breast drain. The premise behind SLNB is that if the sentinel node is free of metastasis, then other lymph nodes in the axilla will also be disease free, and therefore, there is no need to remove the remaining lymph nodes in the axilla. SLNB is used for staging breast cancers. SLNB is done intraoperatively by identifying, removing, and histologically examining the lymph node to determine if the cancer has spread to the lymph system. A radioactive technetium tracer or a blue dye (taken up by lymphatics) is first injected subareolarly. The lymph nodes that are radioactive and/or blue are then considered the sentinel nodes and are removed.

Watch Out

Radioactive technetium tracer used in SLNB in patients undergoing BCT or simple mastectomy has been demonstrated to be safe for use in pregnancy as the tracer remains localized in the breast tissue that is then removed. The blue dye should be avoided as it can potentially harm the fetus.

Why Does SLNB Need to Be Performed at the Same Time as a Mastectomy and Not Later?

If a mastectomy is planned, the SLNB needs to be performed at the same time. Once the breast is removed, SLNB is no longer possible as the breast tissue with accompanying lymphatics have been removed.

Can There Be More than One Sentinel Node?

Yes, in most cases, there are 2–4 sentinel nodes.

What Do You Do if During SLNB No Sentinel Lymph Node Lights Up?

In most cases, the surgeon would proceed to axillary lymph node dissection (ALND). Whether to proceed with ALND depends on several factors, including the tumor status and patient comorbidities (a very elderly patient may forgo ALND).

What Are Contraindications to BCT?

Absolute contraindications are multiple primary tumors in two or more quadrants, diffuse malignant-appearing microcalcifications throughout the breast, previous history of chest wall radiation, positive surgical margins despite repeat excision, and early pregnancy (as radiation cannot be given during pregnancy). However, it is possible to perform BCT in the third trimester of pregnancy and then receive radiation therapy after childbirth. Relative contraindications are a history of collagen vascular disease and large tumors in a small breast in which adequate margins would result in a cosmetically undesired appearance.

Watch Out

In a woman with a history of non-Hodgkin lymphoma (mantle cell lymphoma) that now has invasive breast cancer and might be otherwise a candidate for BCT, prior chest wall radiation treatment prevents her from being able to proceed with BCT and must undergo a simple/total mastectomy.

Can the Nipple and Breast Skin Be Spared During a Simple Mastectomy?

Yes, two other options for tumor resection are skin-sparing and nipple-sparing mastectomy. These approaches lead to less scarring and a more cosmetically appealing breast reconstruction. There are concerns that leaving behind the nipple

areolar complex may increase the risk of developing a new breast cancer or recurrence. This is particularly worrisome in high-risk patients such as those with the BRCA gene. Recent studies suggest that at least in the short term, outcomes are similar to simple mastectomy even in BRCA carriers.

What Are the Management Options for Clinically Advanced (Stage III) Breast Cancers?

Clinically advanced breast cancer (Stage III) includes very large tumors (>5 cm), tumors that have invaded the skin (such as inflammatory breast cancer), or the presence of large matted clinically positive axillary lymph nodes. For these patients, management must be tailored. In most cases these patients will receive chemotherapy before surgery. Also, if the primary tumor is large, breast conservation is not an option, and the patient will require a simple mastectomy. If there are obvious clinically enlarged and matted lymph nodes, then SLNB is not an option, and the patient will require an ALND. If the patient has both a very large tumor and obvious clinically enlarged axillary nodes, then the patient will require a modified radical mastectomy (mastectomy combined with ALND). Similarly, if the patient has inflammatory breast cancer, the chemotherapy may shrink the tumor and clear the skin of tumor, so as to later obtain negative surgical margins.

When Do You Perform Axillary Lymph Node Dissection (ALND)?

ALND involves removing Level I and II nodes. If the sentinel lymph node(s) is (are) positive for metastatic cancer, complete ALND is not necessarily needed. Recent studies have showed the safety of excluding ALND in patients with only 1–2 positive nodes who had undergone breast conservation therapy. Such patients receive radiation to the remaining breast and low axilla, which may obviate the need for ALND.

What Are the Boundaries in the Axilla for Breast Dissection?

There are four boundaries: axillary vein (superior), floor of the axilla (posterior), latissimus dorsi muscle (lateral), and pectoral minor muscle (medial).

To What Structure Are Axillary Lymph Node Levels Referenced?

Axillary lymph node levels are based on their location relative to the *pectoralis minor muscle*. Level I nodes are lateral to the muscle border, Level II nodes are located behind, and

Level III nodes are medial. Rotter nodes are interpectoral (between pectoralis major and minor) and are technically Level II nodes.

Watch Out

In breast cancer, ALND requires removal of Level I and II nodes, while in melanoma, ALND requires removal of Level I, II, and III nodes.

6

What Is the Purpose of Axillary Lymph Node Dissection? Does It Affect Survival?

Axillary lymph node dissection is used for staging of breast cancer; removing the lymph nodes per se has not been shown to improve survival.

What Are the Options for Hormonal Therapy, and What Is the Premise Behind It?

Cancers that are ER + or PR + are candidates for hormonal therapy (Table 6.4). These drugs work by either decreasing the level of steroid hormones in the body or antagonizing the receptors that promote growth of cancer cells. They are most often used as adjuvant therapy to prevent recurrence.

What Study Must Be Done Prior to Starting Trastuzumab?

Since there is a high risk of cardiomyopathy in patients receiving trastuzumab, it is recommended that all patients receive an echocardiogram or a MUGA scan (more sensitive) to determine their ejection fraction.

Why Is an Aromatase Inhibitor (AI) Only Effective in Postmenopausal Women?

AI work by inhibiting the aromatase enzyme, located in fat tissue, which is responsible for making small amounts of estrogen in postmenopausal women. AIs are only effective in women with ovaries that have stopped producing estrogen, which occurs after menopause. The primary source of estrogen for these women is that which is produced in fat cells.

Does Everyone with Breast Cancer Require Chemotherapy?

No. Patients with noninvasive breast cancers (carcinoma in situ) do not benefit from systemic chemotherapy because the cancer cells have little risk for dissemination. In addition, certain very small invasive cancers (<1 cm) with favorable tumor receptors and a negative SLNB may not benefit from chemotherapy. In these patients with favorable tumor characteristics, the *Oncotype-DX* breast cancer test is performed. This test examines the individual patient's tumor characteristics at the molecular level, enabling the clinician to predict the likelihood of chemotherapy benefit as well as recurrence in early-stage breast cancer. Most patients that are ER-/PR- or triple-negative should receive chemotherapy.

What Are the Most Common Chemotherapy Regimens?

Many options are available and should be tailored to the patient's type of breast cancer and personal medical history. The most commonly used drugs fall into four categories (Table 6.5).

Table 6.4 Hormonal therapy in breast cancer

Drug	Mechanism	Features
<i>Tamoxifen</i>	Blocks estrogen receptors	Acts like estrogen in some tissues (endometrial) but antiestrogen in others (<i>selective estrogen receptor modulator</i> or <i>SERM</i>); can be used to decrease incidence in high-risk women; increases risk for <i>endometrial cancer</i> and <i>blood clots</i> ; taken for 5–10 years following surgery; can cause fatigue, hot flashes, and vaginal dryness
<i>Raloxifene</i>	Blocks estrogen receptors	Decreased risk of endometrial cancer when compared to tamoxifen, as effective as tamoxifen in reducing incidence of invasive breast cancer in high-risk postmenopausal women but does not reduce incidence of DCIS or LCIS
<i>Fulvestrant</i>	Blocks estrogen receptors	Works systemically (not a SERM), severe osteoporosis risk, only approved for <i>postmenopausal</i> women that have failed therapy with tamoxifen
<i>Anastrozole</i>	Aromatase inhibitor	Decreases estrogen levels, only effective in <i>postmenopausal</i> women, no risk of endometrial cancer, less risk of blood clots when compared to SERMs
<i>Trastuzumab</i>	Monoclonal antibody blocking HER-2 receptors	Reduces recurrence, improved overall survival, expensive, risk of cardiomyopathy

Table 6.5 Chemotherapeutic regimens for breast cancer

Class	Representatives	Mechanism	Risks
<i>Anthracyclines</i>	Doxorubicin, epirubicin, and idarubicin	Inhibits DNA/RNA synthesis, inhibits topoisomerase II, halting cell growth and division	Hair loss, vomiting, cardiomyopathy
<i>Alkylating agent</i>	Cyclophosphamide	Promotes DNA damage by alkylating guanine bases	Risk of leukemia, cystitis, and bladder cancer
<i>Antimetabolites</i>	Methotrexate and 5-FU	Interferes with DNA synthesis, halting cell growth and division	Hair loss, vomiting, bone marrow suppression
<i>Taxanes</i>	Paclitaxel and docetaxel	Inhibits mitotic phase in cell cycle	Neuropathy

Watch Out

Chemotherapy timed preoperatively (neoadjuvant) versus postoperatively (adjuvant) has the same survival outcome for all breast cancer subtypes.

What Are the Options for Breast Reconstruction? What Is the Timing?

Women undergoing a mastectomy may choose to have additional breast reconstruction surgery to retain their breast shape. The options are to perform an immediate or delayed

reconstruction. Immediate reconstruction can be done with an autologous tissue flap (transverse rectus abdominal muscle or latissimus dorsi) or with a temporary tissue expander. The tissue expander is later replaced by a permanent implant once the skin is sufficiently stretched. If the patient desires an autogenous reconstruction but requires postoperative radiation therapy, then the reconstruction is delayed (as the radiation may compromise the flap). On the other hand, tissue expanders can be placed immediately, regardless of whether radiation therapy is needed. The decision to perform a delayed reconstruction is based on several factors including patient preference, surgeon availability, and patient risk factors.

Complications

What Nerves Are at Risk for Damage During ALND?

Table 6.6

Nerve	Location	Muscle innervated	Deficit if damaged
<i>Long thoracic</i>	Travels along midaxillary line	Serratus anterior	Upward rotation, abduction, and weak elevation of the scapula (winged scapula)
<i>Thoracodorsal</i>	Travels lateral to long thoracic nerve	Latissimus dorsi	Weak extension, adduction, and internal rotation of shoulder joint
<i>Medial pectoral</i>	Travels lateral to or through the pectoral minor muscle and lateral to the lateral pectoral nerve	Pectoral minor and major	Weak internal rotation of humerus
<i>Lateral pectoral</i>	Travels medial to the medial pectoral nerve	Pectoral major	Weak flexion, adduction, and internal rotation of humerus

What Is the Most Morbid Complication of Lymph Node Dissection?

Lymphedema is the most morbid complication, resulting from the disruption of the normal flow within the lymph system. ALND is associated with a greater risk of lymphedema than SLNB. Lymphedema can lead to significant pain and disability in the affected arm. Patients with lymphedema also have an increased risk of cellulitis owing to the inability to properly mobilize the immune system. In chronic cases, patients may develop lymphangiosarcoma (*Stewart-Treves syndrome*), which has a very poor prognosis even after limb amputation. For these reasons, SLNB is useful as it prevents unnecessary ALND.

Areas You Can Get in Trouble

Confusing Inflammatory Breast Carcinoma with Cellulitis

Inflammatory breast carcinoma is characterized by carcinoma in subdermal lymphatics producing an inflamed, swollen breast with no discrete mass. These patients are often initially misdiagnosed as having acute mastitis or cellulitis and treated with a course of antibiotics. The prognosis is poor because cancer cells have already infiltrated the lymphatics. Patients are *initially* treated with chemotherapy which is followed by mastectomy and then radiation.

Ignoring a Breast Mass During Pregnancy

Traditionally, breast cancer in pregnancy has been rare. Stage for stage, prognosis appears to be the same as for nonpregnant women. However, pregnant women with breast cancer are often diagnosed at later stages. This is a result of denser breast tissue which can make breast masses harder to visualize on mammogram. In addition, the hormonal changes that take place during pregnancy can obscure any signs or symptoms that may have otherwise prompted a patient to seek a doctor's advice. A pregnant patient's breast is larger, more tender, and lumpier. Delayed diagnosis remains to be the biggest challenge in dealing with breast cancer in pregnancy. In general, women *can safely be given chemotherapy during the second trimester* (weeks 12–27) and undergo a simple mastectomy during the second trimester. If a patient is diagnosed during the third trimester and requires chemotherapy, it is delayed until after she gives birth. Radiation and hormonal therapy are *never* recommended during pregnancy. BCT is an appropriate option during the third trimester with the radiation postponed until after delivery.

Ignoring a Breast Mass in an Elderly Male

Men have breast tissue and as such can also develop breast cancer. Breast cancer in males is rare (1% of all breast cancers) with most cases identified as invasive ductal carcinoma.

DCIS is less common as most men present late, with a palpable mass. Since lobules are not fully formed in men, LCIS and lobular breast cancer are extremely rare. The biggest risk factor is age, with most men diagnosed between 65 and 70 years. High estrogen levels promote breast cell growth which can lead to cancer. Hormonal medications, obesity, alcohol abuse, cirrhosis, and Klinefelter syndrome can all lead to high serum estrogen levels. Additional risk factors include family history of breast cancer, genetic defects (BRCA-2 is a stronger risk factor in men), and radiation therapy to the chest wall (e.g., Hodgkin's disease). The impression that breast cancer in males has a worse prognosis when compared to women may be a result of diagnosing men at later stages of the disease. However, the overall survival is similar to that of women with the same stage of breast cancer.

Watch Out

Gynecomastia is *not* a risk factor for male breast cancer.

Areas of Controversy

Should Mastectomy Be Performed in Patients with Stage IV (Metastatic) Breast Cancer?

The prognosis for Stage IV (metastatic) breast cancer is poor. Given that the tumor has already spread to other organs, the benefit of removing the primary tumor is questionable. Nevertheless, several studies suggest that mastectomy in select patients with Stage IV breast cancer provides some survival benefit.

Should BCT Patients Receive Intraoperative Radiation?

Patients that undergo BCT must get radiation treatment to the breast to reduce the risk of local recurrence. Until recently, the only option was to receive several rounds of radiation treatment weeks after recovering from surgery. The TARGIT-A trial has demonstrated that intraoperative radiation done during the time of BCT is equally effective when compared to conventional external radiation. The advantage is that the patient only undergoes one round of radiation and at the same time of surgery. This is not yet the standard of care. A phase-IV trial is currently underway.

Summary of Essentials

History and Physical

- A new breast mass in postmenopausal women is cancer until proven otherwise.
- Breast cancer: firm with irregular borders.

- Nipple discharge that is bloody, spontaneous, unilateral, uniductal, and associated with a breast mass or occurs in women over 40 years is more suspicious for cancer.
- Risk factors: family history, genetic defects (BRCA-1 or BRCA-2), obesity, early menarche, late menopause, nulliparity or childbirth after age 30, alcohol, and radiation to the chest.

Etiology/Pathophysiology

- Fibrocystic disease: most common cause of a palpable breast mass.
- One in eight women in the United States will develop breast cancer.
- Invasive ductal carcinoma: most common malignant breast neoplasm.
- Fibroadenoma: most common breast neoplasm in premenopausal women.
- Triple-negative breast cancer: negative for estrogen, progesterone, and HER-2 receptors.

Diagnosis

- Apply triple test (physical exam, imaging, tissue sample) to all new breast masses.
- Imaging:
 - ≤30 years old – ultrasound
 - >30 years old – mammogram plus ultrasound
- Tissue diagnosis is indicated for any clinically suspicious mass regardless of imaging findings.
- FNA cannot accurately differentiate in situ from carcinoma; thus core needle biopsy is better.
- Metastatic workup for clinically early-stage breast cancer not needed: chest X-ray, liver chemistries, and alkaline phosphatase only if symptoms or signs present.
 - Bone scan and CT of the abdomen, chest, and brain only if suspicion for metastasis is high based on lab tests or clinical Stage III disease or symptoms.

Management

- For early stage (I or II):
 - Lumpectomy, SLNB, and radiation (BCT)
 - Equal in terms of survival.
- Higher local recurrence rate:
 - Simple mastectomy with SLND
 - No radiation if early stage but will need radiation if more advanced.
- SLNB:
 - Average 2–4 sentinel nodes
 - Less lymphedema than ALND
 - If positive for metastasis may need ALND
- Level I and II nodes.

- For Stage III cancers, treatment must be individualized:
 - For inflammatory breast cancer, neoadjuvant chemotherapy followed by modified radical mastectomy and then radiation therapy.
 - For large tumors, BCT not an option.
 - For clinically positive axillary lymph nodes, SLNB not an option; proceed to ALND.
- Drugs:
 - Trastuzumab for HER-2 positive.
 - Tamoxifen for premenopausal estrogen receptor positive.
 - Anastrozole (aromatase inhibitor) for postmenopausal estrogen receptor positive.
 - Most patients receive hormonal therapy.

Complications

- Axillary lymph node dissection can lead to significant morbidity.
 - Lymphedema.
 - Nerve injury (long thoracic, thoracodorsal, medial, and lateral pectoral nerves).

Watch Out

- Men can get breast cancer (usually invasive ductal carcinoma).
- Do not confuse inflammatory breast cancer with cellulitis.
- Do not ignore breast masses during pregnancy or in younger women.

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Recently Changed Skin Lesion

Arezou Yaghoubian and Junko Ozao-Choy

Case Study

A 44-year-old fair-skinned Caucasian male who works as a life-guard presents with a 1 cm pigmented skin lesion on the right forearm that has recently changed colors and become larger in diameter. The patient denies itching, oozing, or bleeding associated with the lesion. He has a history of severe blistering childhood sunburns. The lesion is slightly elevated and asymmetric with ill-defined borders. There is no evidence of bleeding, ulceration, or excoriation. There are no satellite or in-transit lesions seen. Examination of the patient's right axilla and neck reveals no obvious lymphadenopathy. No other skin lesions are identified on physical examination.

7

Diagnosis

What Is the Differential Diagnosis?

Table 7.1

Diagnosis	Malignant?	Comments
<i>Junctional nevi</i>	No	Dark, flat, smooth lesions; they are occasionally hairy and develop from the basal layer of epidermis; nevi that are located on the palms and soles are usually junctional; they are benign lesions with a very low risk of malignant degeneration; <i>most common mole in children</i>
<i>Compound nevi</i>	No	Brown to black, well-circumscribed lesions that are <1 cm in diameter; they may be elevated and are frequently hairy, arising from the epidermal-dermal interface and from within the dermis; malignant transformation is rare
<i>Intradermal nevi</i>	No	Light-colored, well-circumscribed lesions <1 cm in diameter; hairs are usually present, and the cell distribution occurs in the dermis; <i>most common mole in adults</i>
<i>Giant pigmented nevi</i>	No	Brown to black hairy lesions with an irregular nodular surface; they are frequently described as a bathing trunk type of lesion; <i>excision is recommended</i>
<i>Spitz nevi</i>	No	Smooth, round, pink-black lesions measuring 1–2 cm in diameter found mainly in children; they have increased cellularity and occur in nests within the upper dermis; atypical nevi have a small risk of malignant degeneration
<i>Pigmented actinic keratosis</i>	No	Premalignant lesions caused by sun exposure, sandpaper texture, small, rough, erythematous, or brownish papules, often on the face, back, or neck, also called “cutaneous horn”
<i>Keratoacanthoma</i>	No	Well-differentiated tumor originating from the pilosebaceous glands, develops rapidly and regresses spontaneously (outgrows blood supply and necroses) and presents as a cup-shaped tumor filled with keratin debris
<i>Seborrheic keratosis</i>	No	Common tumor in elderly presents as raised, discolored plaques, coin-like, waxy, “stuck-on” appearance
<i>Dysplastic nevus</i>	No	Large, pigmented lesions, irregular border, frequently occur on the back, chest, buttocks, breast, and scalp and can be found in sun-exposed and sun-protected areas
<i>Melanoma</i>	Yes	Proliferation of melanocytes, most common cause of death from skin cancer, presents as mole-like growth with “ABCD” (see below)
<i>Squamous cell carcinoma (SCC)</i>	Yes	Proliferation of squamous cells characterized by formation of keratin pearls presents as ulcerated, nodular, mass with no telangiectasias, usually on the face (classically involving the lower lip)
<i>Basal cell carcinoma (BCC)</i>	Yes	Most common cutaneous malignancy presents as elevated, pearl-like nodule with a central, ulcerated crater surrounded by telangiectasias (classically involving the upper lip)
<i>Metastatic tumors to the skin</i>	Yes	In males, the most common sources are malignant melanoma (30%), lung, colon, carcinoma of the oral cavity, larynx, and kidney; in females, the most common sources are breast (70%), followed by melanoma, and ovary

What Is the Most Likely Diagnosis?

In a patient presenting with a recently changed skin lesion that has become variegated and larger in diameter with an asymmetric, irregular border, the most likely diagnosis is melanoma. Additionally, the patient's fair-colored skin, occupation as a lifeguard, and history of blistering childhood sunburns further increase his risk of developing skin cancer.

History and Physical

What Risk Factors for Skin Cancer Are Common to SCC, BCC, and Melanoma?

A common pathway for increased risk for skin cancer (SCC, BCC, and melanoma) is excessive exposure to ultraviolet (UV) light, particularly UV-B (remember, B for Bad). Immunosuppression is another recognized risk factor. For SCC and BCC, the risk is greatest with cumulative long-term UV exposure. With melanoma, both blistering sunburns and overall sun exposure are risk factors. Skin cancer is also more common in patients who have fair-colored skin and hair as well as in those with blue eyes.

What Factors During Childhood/Teen Years Are Associated with an Increased Risk of Skin Cancer?

A blistering sunburn in childhood or adolescence more than doubles the chance of developing skin cancer, as does the use of a tanning salon.

What Genetic Conditions Are Associated with an Increased Risk of Skin Cancer?

Xeroderma pigmentosum is a rare autosomal recessive condition that leads to photosensitivity due to deficient repair of DNA damaged by UV radiation. It leads to a very high rate of melanoma, BCC, and SCC at an early age.

What Occupations Are Highly Associated with Skin Cancer?

Occupations that involve long-term sun exposure place patients at higher risk, such as a lifeguard, farmer, construction worker, gardener, and field worker.

Table 7.2 "ABCDEs" of melanoma

A	Asymmetry of lesion	Is the lesion round and symmetric or does it look asymmetric?
B	Border irregularity	Do the borders of the lesion seem smooth and circumscribed or are they jagged and indistinct?
C	Color variegation (different colors)	Does the lesion have one even pigmented color or does it have several shades of pigment?
D	Diameter > 6 mm	Is the lesion bigger than about the size of a pencil eraser?
E	Evolution (changing lesion)	Are there any big changes such as rapid growth, bleeding, or ulceration in the lesion?

What Are Findings on Physical Examination that Differentiate a Benign Nevus from Melanoma?

The "ABCDEs" of melanoma (Table 7.2) can serve as a memory tool to help remember the common differentiating characteristics.

Watch Out

Hair growth on a skin lesion suggests that it is a benign nevus. Melanomas destroy hair follicles.

What Is the Ugly Duckling Sign?

The ugly duckling sign is a concept that emerged after recognizing the limitations in the ABCDE mnemonic. Any skin lesion that looks different or out of place and thus an "ugly duckling" in a nest of other similar appearing lesions is suspicious and recommended for biopsy.

Why Is It Important to Inquire About and Examine Areas of Chronic Skin Inflammation?

Chronic skin inflammation is a known risk factor for SCC. It can develop in chronic open burn wounds (Marjolin's ulcer), chronic venous ulcers, and long-standing skin infections such as hidradenitis suppurativa and human papillomavirus.

Watch Out

Chronically non-healing wounds should be biopsied to rule out malignancy.

On What Areas of the Skin Are Melanomas Most Likely to Occur in Nonwhite Ethnicities?

In black, Asian, and Hawaiian populations, melanomas most often occur on areas of nonexposed skin with less pigment such as the palms, soles, mucous membranes, and nail regions.

7

What Is the Most Common Site of Melanoma in Men Versus Women?

For men, the back is the most common site, while the legs are the most common site for women.

What Is the Most Common Site of Digital Melanoma?

Great toe. Toe amputation and sentinel lymph node biopsy are the preferred treatment.

Does the Regular Use of SPF Protection Reduce the Risk of Skin Cancer?

Yes, regular daily use of an SPF-15 or higher sunscreen reduces the risk of developing squamous cell carcinoma and melanoma by about half.

What Is an “In-Transit” Metastasis? Satellite Lesion?

An in-transit metastasis is a skin lesion (particularly seen in melanoma) that represents extension of the primary tumor that has grown via a lymph vessel. Such in-transit metastases are more than 2 cm away from the primary tumor and in the direction of the nearest lymph node bed. Satellite lesions are metastatic lesions that are less than 2 cm from the primary. Both represent lymphatic tumor spread.

Pathophysiology

What Is a Nevus? What Are Dysplastic Nevii? Are Nevii a Risk for Malignant Transformation? What Is Dysplastic Nevus Syndrome?

A nevus is a mole. It is very rare for common moles to become malignant. Dysplastic nevi are irregular looking moles, often with a raised center (“fried egg” appearance) that are either

bigger, have different colors, or irregular borders. Though they are benign, there is a low risk that they can become malignant. Patients with 50 or more common moles or those with 10 or more dysplastic nevi are at increased risk of developing melanoma. However, melanoma most often develops in areas of skin without nevi. As such there is no reason to remove common or dysplastic nevi. Dysplastic nevus syndrome (also called familial atypical multiple mole-melanoma syndrome) is an autosomal dominant disorder characterized by multiple dysplastic nevi with increased risk for progression toward melanoma (10% risk). These patients have a family history of melanoma, 100 or more moles, and at least 2 large dysplastic nevi.

From Where Does Melanoma Arise?

Melanoma originates from melanocytes, which are derived from neural crest cells. It can arise from a preexisting nevus or de novo as a new pigmented lesion (although a small percentage can be *amelanotic*).

What Is the Most Common Skin Cancer? Second Most Common? Which Skin Cancer Is Associated with the Greatest Number of Deaths?

Basal cell carcinoma is the most common skin cancer (and most common overall cancer), followed by squamous cell cancer, whereas melanoma accounts for the most deaths.

What Is the Most Common Precancerous Skin Lesion?

Actinic keratosis is the most common precancerous skin lesion. It is a rough scaly epidermal lesion that occurs in an area of the body subjected to chronic sun exposure. The risk of actinic keratosis undergoing malignant transformation to SCC is about 1% per year. Some actinic keratosis can be pigmented.

What Is Bowen’s Disease?

It is a squamous cell carcinoma in situ. It appears as a well-defined erythematous plaque covered by an adherent scaly yellow crust. There is no potential for metastasis.

What Is the Metastatic Risk of BCC, SCC, and Melanoma?

Basal cell carcinoma can be locally destructive; however, metastases are rare. Squamous cell carcinomas do metastasize, but much less commonly than melanoma. The most

common site for melanoma to metastasize is to *other areas of the skin*, followed by the lung, liver, brain, and bone.

Watch Out

The most common metastasis to the small bowel is melanoma.

What Are the Four Subtypes of Melanoma?

Table 7.3

Type	Prevalence	Features
<i>Superficial spreading</i>	50–60%	Most common type of melanoma typically has a long horizontal growth phase before the vertical growth phase, therefore better prognosis
<i>Lentigo maligna</i>	4–10%	Lentiginous proliferation indicates the tumor remains at the junction, best prognosis, aka “Hutchinson freckle”
<i>Acral lentiginous</i>	2–3%	Typically found in the subungual, sole, or palm location, common in ethnic groups of color; <i>not</i> related to UV light exposure
<i>Nodular</i>	10–30%	Worst prognosis due to rapid vertical growth, increased metastatic potential, 5% amelanotic

Watch Out

Lentigo maligna has the best prognosis of the four melanoma subtypes; remember, *Lentigo is least aggressive*.

What Is the Difference Between Clark Classification and Breslow Depth?

Clark classification of melanoma is a form of staging based on the layer of the skin involved with tumor. This was measured by anatomic levels (i.e., involvement of epidermis vs. reticular dermis) and is currently not used in staging. *Breslow depth* is based on the actual depth of invasion, which is the vertical height of the melanoma from the granular layer to the deepest area of penetration and is measured in millimeters. Compared to the Clark method, Breslow depth of invasion is a more accurate prognostic indicator (Table 7.4). Breslow thickness correlates directly to the risk of local recurrence, metastasis, and survival rate.

Table 7.4 Breslow thickness 5-year survival

Depth	5-year survival
<0.75 mm	95–100%
0.75–1.5 mm	80–96%
1.5–4.0 mm	60–75%
>4.0 mm	50%

Workup

What Are the Different Types of Skin Biopsy?

All suspicious skin lesions should undergo a biopsy. Options include excisional or incisional biopsy. An incisional biopsy only removes part of the lesion so as to establish the diagnosis. If it is benign, this avoids removing the entire lesion (which might be disfiguring and unnecessary). An excisional biopsy removes the entire lesion. This is best suited for small lesions.

Shave biopsies (done with razor blade or scalpel) remove a slice or disk of the skin and are used for lesions that appear to be limited to the epidermis such as skin tags, warts, suspected actinic keratosis, or suspected basal cell cancer. Shave biopsies are not recommended if melanoma is suspected as the true Breslow thickness can be miscalculated by this biopsy method.

When lesions are large, when a sample of dermis or subcutaneous tissue is desired (such as a large suspicious mole), or the lesion is in a location (such as the face) where complete excision might be cosmetically unappealing, a punch biopsy is used. Such a biopsy extends into the dermis and subcutaneous tissue. If the final pathology is benign, this avoids having to then excise the whole lesion. If the lesion demonstrates skin cancer, the whole lesion will need to be subsequently excised with varying margins (see below).

For the patient in this vignette, a shave biopsy would be inappropriate given the concern for melanoma. A punch biopsy would be a good option or an excisional biopsy (given that the lesion is relatively small and located in the forearm (and not face)).

Once the Diagnosis of Melanoma Is Established, What Additional Studies Should Be Obtained?

Further screening workup should include a chest X-ray, complete blood count, liver function tests, and serum lactate dehydrogenase (LDH) to rule out metastatic disease. LDH is a prognostic indicator in melanoma and has been found to be indicative of liver metastases. If clinically palpable lymph

nodes are present in the setting of a melanoma, the patient should undergo a CT scan of the chest, abdomen, and pelvis and a PET scan to rule out metastatic disease. An MRI of the brain may also be indicated if the patient has symptoms of CNS metastasis (e.g., motor deficits, seizures, headaches).

What Are Poor Prognostic Indicators with Melanoma?

Thicker lesions, *ulceration*, location on trunk, and male gender

Management

What Treatment Options Exist for SCC and BCC?

Table 7.5

Treatment	Comments
<i>Electrodissection/curettage</i>	Can result in a 95% cure rate; however, disadvantage is a lack of specimen for determining adequacy of resection
<i>Topical therapies</i>	Includes imiquimod, 5-FU
<i>Surgical excision</i>	Removes entire melanoma with border of normal appearing skin
<i>Radiation</i>	Recommended choice when excision not possible or used as adjuvant therapy when there are high-risk lesions
<i>Cryotherapy</i>	Liquid nitrogen is used to freeze cancerous tissue and destroy it

What Is the Primary Therapy for BCC/SCC Skin Cancers?

Complete surgical excision of the lesion with negative margins. Patients with lesions in cosmetically sensitive areas, aggressive tumor features, ill-defined lesions, or recurrent BCC/SCC are candidates for Mohs surgery.

What Type of Surgical Margins Do You Need for BCC vs. SCC?

BCC needs 3–5 mm, while SCC needs 5–10 mm.

Watch Out

If margins are positive, it is essential to re-excise the incision to clear margins.

Table 7.6 Melanoma excision

Tumor thickness	Excision margin	Lymph node treatment
<i>Melanoma in situ</i>	0.5 cm	None
<i>0–0.75 mm</i>	1 cm	None
<i>0.75–1 mm</i>	1 cm	SLNB for high-risk features ^a
<i>1–2 mm</i>	1–2 cm	SLNB
<i>2–4 mm</i>	2 cm	SLNB
<i>>4 mm</i>	2 cm ^b	SLNB

^aLymphovascular invasion, Clark IV or V, positive deep margin on biopsy, ulceration, and mitoses

^bNo randomized controlled studies have specifically addressed this cohort

Which Type of Basal Cell Carcinoma Has the Worst Prognosis?

Morpheaform, which is characterized by *collagenase* production.

How Is Melanoma Surgically Managed?

Once the diagnosis is established by punch or excisional biopsy, the area needs to be re-excised to obtain wider margins (Table 7.6), and in select cases, sentinel lymph node biopsy (SLNB) is obtained. The extent of margins and need for SLNB are determined by tumor thickness.

What Is the Purpose of the SLNB, and How Is It Performed?

SLNB is a way of determining whether the patient has clinically occult regional lymph node metastases. If the sentinel lymph node is cancer free, SLNB avoids the need to perform a complete lymph node dissection, which is associated with significant risk of permanent lymphedema. After performing lymphoscintigraphy (lymphatic mapping to see where melanoma drains), SLNB permits sampling the first lymph node that drains from the area of the malignancy.

What Are the Indications for Lymph Node Dissection?

Lymph node dissection is reserved for patients with clinically palpable lymphadenopathy or those with a positive SLNB. An area of controversy is what to do if the lymph node only demonstrates micrometastasis (small clumps of cancer cells in the node as opposed to gross replacement of node with cancer). To date, no published data from prospective trials

are available on the clinical significance of micrometastatic melanoma in regional lymph nodes, but some evidence suggests that for patients with tumors of intermediate thickness and occult metastasis, survival is better among those patients who undergo immediate regional lymphadenectomy than it is among those who delay lymphadenectomy until the clinical appearance of nodal metastases. Axillary lymph node levels I, II, and III are removed during axillary lymph node dissection for melanoma.

How Is Melanoma of the Fingernail Managed?

Amputation through the joint, just proximal to the lesion. Acral lentiginous melanoma is found beneath the nail, on the palm of the hand, or on the sole of the foot. These lesions represent approximately 3% of all cutaneous melanomas. The prognosis for subungual melanomas is worse than for other cutaneous melanomas, probably because of delay in diagnosis.

What Is the Prognosis for Melanoma?

When disease is confined to the primary site, 5-year survival is 80–90%. If lymph nodes are involved, this decreases to 30–50%. Those with distant metastases have poor prognosis (10–15% 5-year survival).

What Is the Follow-Up Protocol for Melanoma?

Thorough physical examination at 3–6-month intervals over the course of the first 3 years. Recurrent disease occurs locally, regionally, or systematically. Regional lymph node disease is the most common type of recurrence. The patient should also be sent for imaging depending on the stage of disease.

What Is Mohs Surgery? What Are the Main Indications for Its Use? Is It Appropriate for the Treatment of Melanoma?

Mohs is a specialized technique of treating skin cancer named after Dr. Frederic Mohs. Its design is unique in that it integrates the role of the surgeon and pathologist to allow for identification of 100% of surgical margins intraoperatively. Mohs involves tangential excisions of the lesion until margins are negative. Mohs has the advantage in that definitive excision and closure can be achieved on the same day. It also offers excellent cure rates and can achieve accurate margins, especially on the head, neck, hands, and other areas with a high risk of recurrence. In addition to the high cure rate, Mohs surgery is a tissue-sparing procedure. The need for wide, extensive excision is reduced because of the precise control of tumor margins. This is an important advantage in

cosmetically and functionally sensitive areas. A disadvantage of Mohs is the difficulty associated with adequately preparing frozen sections for visualization of melanocytes, including the need for immunohistochemical stains. Because of this, Mohs is considered an unreliable method of resection for melanoma.

Areas Where You Can Get in Trouble

Assuming that a Discolored Nail Bed Is a Benign Condition

Blackened or darkened toenails may represent benign conditions and may be difficult to distinguish from a subungual melanoma on physical examination. Benign conditions include subungual hematoma (bleeding under the nail bed from trauma), benign streaks in the nail plate, benign subungual nevus, and onychomycosis. Dermoscopy can be helpful in distinguishing melanoma from a subungual hematoma. If the area is suspicious, a full thickness biopsy through the nail bed should be performed. The presence of atypia or melanoma in situ requires complete excision with clear margins.

Pink Nodule Progressing to a Blue Color in an Immunocompromised Patient

Elderly patients that are immunocompromised (e.g., HIV, lymphoma, leukemia) may develop Merkel cell carcinoma (MCC) which is thought to arise from specialized touch receptor cells in the epidermis of the skin. The majority of patients are infected with Merkel cell polyomavirus. The nodule first appears pink and progresses to a blue violaceous color and rapidly expands. Treatment involves wide local excision with 1–2 cm margins, SLNB, and radiation.

Relying Solely on the ABCDE Rule for Detecting Melanomas

Not all melanomas follow the ABCDE rule. Nodular melanomas do not. These are usually a uniformly dark blue or black “berry-like” lesion that is mostly symmetric, elevated, and one colored. They grow vertically, not horizontally. In addition, there are a subset of melanomas which may not even be pigmented (amelanotic melanoma). Also some melanomas, with careful exam, can be detected at a diameter of less than 6 mm.

Recurrent Infections Around Gluteal Cleft

This is concerning for a pilonidal cyst and can present acutely as an abscess or with chronic drainage. The typical location is the upper border of the intergluteal cleft. Obesity and sedentary lifestyle are risk factors. If the patient presents with an abscess, the treatment is incision and drainage. The treat-

ment for chronic pilonidal cysts is complex, but most require excision with primary closure or flap reconstruction.

Areas of Controversy

Is There Any Benefit for Surgical Resection for Stage IV (Distant Metastasis) Melanoma?

A study in 2012 evaluating data from the MSLT-I trial demonstrated benefit of metastasectomy (resection of metastatic lesions) in patients with stage IV resectable disease. The study demonstrated that select patients with resectable stage IV disease had improved survival following surgical resection, regardless of the location or the number of metastases as compared to systemic medical therapy.

Is Adjuvant Therapy Beneficial for Advanced Melanoma?

There has been no concrete evidence that adjuvant therapy prolongs survival in melanoma. Options include regional hyperthermic perfusion, chemotherapy using dacarbazine, or immunotherapy with interferon. There is some evidence to suggest that there is an improved relapse-free survival and overall survival with high-dose interferon alpha-2b. For patients with in-transit and/or satellite lesions of the extremities, hyperthermic isolated limb perfusion with melphalan with or without TNF-alpha has resulted in high tumor response rates and palliative benefit.

Are There Medical Therapies for Metastatic Melanoma Patients?

Ipilimumab, a CTLA-4 blocking antibody, and vemurafenib, a small molecule inhibitor which blocks B-raf, have both been shown to improve overall survival in metastatic melanoma in phase III randomized controlled trials. IL-2 was one of the first treatments approved by the FDA in 1998; however, no improvement of overall survival has been demonstrated in randomized trials. Dacarbazine was approved in 1970 based on overall response rates; however, no effect on overall survival has been demonstrated in randomized trials.

Melanoma Recurring Many Years After Initial Presentation

Patients may present in late adulthood with metastatic lesions and an undiagnosed primary tumor. These patients will often have a clue on H&P that indicates a resected melanoma tumor from early in life (i.e., missing toe). Melanomas sometimes have long time intervals between the initial tumor

and recurrence. A patient with a history of melanoma who presents with a small bowel obstruction should be suspected of having metastatic melanoma to the small bowel.

Summary of Essentials

History and Physical

- New skin lesions require a thorough skin assessment and clinical evaluation of relevant nodal basins.
- ABCDEs of melanoma can help differentiate from a benign nevus.

Differential Diagnosis

- Benign nevi
 - Spitz tumor, junctional nevi, compound nevi, intradermal nevi, and giant/congenital pigmented nevi
- Other benign and precancerous
 - Actinic keratosis, dermatofibroma, keratoacanthoma, seborrheic keratosis, and dysplastic nevus
- Cancer
 - BCC, SCC, and melanoma

Pathology/Pathophysiology

- Skin cancer incidence: BCC > SCC > melanoma.
- Metastatic risk: melanoma > SCC > BCC (can be locally destructive, metastasis rare).
- Melanoma is a proliferation of melanocytes, derived from neural crest cells.
 - Melanoma staged by Breslow based on depth of invasion

Workup

- Biopsy all suspicious lesions
 - Excisional biopsy if small
 - Punch biopsy if large
- Melanoma
 - CXR, LFTs, LDH, and CBC
 - PET and CT if clinically palpable nodes

Management

- Melanoma
 - Re-excite with margins based on Breslow depth
 - Selective SLNB based on Breslow depth
 - Adjuvant therapy of questionable value

- BCC/SCC
 - 3–5 mm margins (BCC)
 - 5–10 mm margins (SCC)
- Mohs
 - Tissue sparing
 - For cosmetically sensitive areas

Watch Out

- Shave biopsies should not be performed for suspected melanoma.
- Nodular and amelanotic melanomas do not follow the ABCDE rule.

Suggested Reading

Balch CM, Gershenwald JE, Soong SJ, et al. Final version of 2009 AJCC melanoma staging and classification. *J Clin Oncol.* 2009;27:6199.

Markovic SN, Erickson LA, Rao RD, et al. Melanoma Study Group of the Mayo Clinic Cancer Center, Malignant melanoma in the 21st Century, part 1: epidemiology, risk factors, screening, prevention, and diagnosis. *Mayo Clin Proc.* 2007;82(3):364–80.

Rigel DS, Russak J, Friedman R. The evolution of melanoma diagnosis: 25 years beyond the ABCDs. *CA Cancer J Clin.* 2010;60:301.

Question Set: *Breast and Skin*

Questions

1. A 15-year-old girl develops short gut syndrome following resection of bowel secondary to leiomyosarcoma in the small intestinal wall. She is subsequently placed on long-term total parenteral nutrition (TPN) and is recovering well. A month later, she develops red and inflamed patches of dry and scaly skin around her mouth and eyes. Her hair also begins to thin, and she notices a bad taste when she gets her daily cherry-flavored Chloraseptic spray to prevent dry throat. What is the most likely underlying etiology of her skin lesions and thinning hair?
- (A) Zinc deficiency
 - (B) Copper deficiency
 - (C) Pemphigus vulgaris
 - (D) Chromium deficiency
 - (E) Psoriasis
2. Which of the following would be best suited for Mohs surgery?
- (A) Superficial spreading melanoma in the arm
 - (B) Nodular melanoma on the back
 - (C) Basal cell carcinoma on the face
 - (D) Subungual melanoma
 - (E) Squamous cell carcinoma of the neck
3. A 36-year-old woman is evaluated for a lump in her right breast that she noticed 5 months ago. She denies any nipple discharge, retraction, or skin changes. She has no family history of breast cancer. On physical exam, the breasts appear normal. Palpation reveals a 1 cm dominant lump in the left upper quadrant of the right breast that does not appear to be fixed to the surrounding structures. The patient has no other dominant masses in either breast. There is no axillary lymphadenopathy. Mammogram is negative. What is the next step in the management?
- (A) Ultrasound-guided core needle biopsy
 - (B) Fine-needle aspiration (FNA)
 - (C) MRI
 - (D) Follow-up clinical breast exam in 3 months
 - (E) Genetic testing
4. A 31-year-old breastfeeding female comes to the doctor for localized swelling, redness, and pain of the left breast. She also reports muscle aches and fatigue. On physical exam her temperature is 38.0 °C, pulse is 82/min, blood pressure is 126/68 mmHg, and respirations are 16/min. Physical exam reveals a localized area of erythema and warmth in the left breast with no palpable masses. There is no axillary lymphadenopathy. What is the most likely next course of action?
- (A) Biopsy
 - (B) Antibiotic treatment and continue breastfeeding
 - (C) Antibiotic treatment and encourage bottle-feeding only
 - (D) Diagnostic mammography
 - (E) Incision and drainage

5. A 33-year-old female of Scottish descent presents with a nodule on her face near the corner of her eye. The lesion measures 13 mm in diameter. The borders are irregular, and the center of the lesion is dark. Which of the following is the best recommendation?
- (A) Shave biopsy
 - (B) Punch biopsy
 - (C) Excisional biopsy with 1 mm margin
 - (D) Excisional biopsy with 5 mm margin
 - (E) Reexamination in 2 months
6. A 71-year-old woman is evaluated for a lump in her right breast that she noticed 3 weeks ago. She denies any nipple discharge, retraction, or skin changes. She has a sister diagnosed with breast cancer at the age of 57. The patient had menarche at the age of 9 and menopause at the age of 56. She had two children, one at the age of 39 and the other at the age of 41. On physical exam, the breasts are normal on inspection. Palpation reveals a 1.5 cm dominant lump that does not appear to be fixed to the surrounding structures. The patient has no other dominant masses in either breast. There is no axillary lymphadenopathy. What is the strongest risk factor in this patient predisposing her to breast cancer?
- (A) Early menarche
 - (B) Family history of breast cancer
 - (C) Older age
 - (D) Age at first pregnancy
 - (E) Late menopause
7. A 50-year-old woman comes to the clinic to discuss treatment for a new diagnosis of breast cancer. Her annual screening mammogram revealed a 1.3 cm mass in the right breast. The patient does not have any other breast masses, skin changes, nipple discharge, or axillary adenopathy. Mammography revealed no other suspicious calcifications within the breast. Biopsy of the mass was performed and revealed infiltrating ductal carcinoma. Estrogen receptor, progesterone receptor, and HER2/neu receptor testing were negative. Which of the following is the best option for the management of this patient's breast cancer?
- (A) Lumpectomy and breast irradiation
 - (B) Lumpectomy and hormone therapy
 - (C) Lumpectomy and chemotherapy
 - (D) Lumpectomy, sentinel node biopsy, and breast irradiation
 - (E) Lumpectomy, sentinel node biopsy, breast irradiation, and chemotherapy
8. A 65-year-old woman presents to her family physician with a pruritic, erythematous, ulcerated rash surrounding the areola of her right breast. She recently started a new medication, hydrochlorothiazide, for hypertension. She is prescribed hydrocortisone 1% ointment, but the lesion persists 3 months later. She has no history of skin diseases in the family. She takes warfarin for atrial fibrillation. Otherwise, she is healthy. What is the best next step in the management of this patient?
- (A) Punch biopsy of the skin lesion
 - (B) Change hydrocortisone 1% to triamcinolone to treat eczema
 - (C) Treatment with antibiotics
 - (D) Oral steroid course to treat psoriasis
 - (E) Increase the dose of hydrocortisone
9. A 64-year-old man who emigrated from Japan arrives to his doctor to discuss new skin lesions. His wife first noticed two discolored plaques on his back 2 weeks ago, but he now has multiple lesions all over his back, chest, and face. They are the size of a coin and appear to have a "stuck-on" appearance. He is afebrile, blood pressure is 136/86 mmHg, and he has a pulse of 90/min. The skin lesions do not itch, and they

are not tender. He has no other complaints, and a review of systems is negative. He is more concerned about his cosmetic appearance. What is the best next step in management?

- (A) Reexamine in 2 weeks
- (B) Skin biopsy
- (C) Abdominal CT scan
- (D) Mohs procedure
- (E) Corticosteroids

10. A 45-year-old female undergoes screening mammography which demonstrates an area of suspicious microscopic calcification in her right upper outer breast. Stereotactic-guided biopsy confirms ductal carcinoma in situ (DCIS). Which of the following is true about this condition?
- (A) It should be excised to a negative margin.
 - (B) It is considered a marker for malignancy in either breast.
 - (C) The cribriform type has a worse prognosis than the comedo type.
 - (D) It does not occur in men.
 - (E) Radiation therapy is an acceptable alternative to surgical excision.
11. A 30-year-old female presents with bloody discharge from her left breast that she has noticed intermittently for the past month. She denies any palpable breast mass, weight loss, fevers, or night sweats. She has no medical history or family history of breast cancer. The skin around the breast and areola are normal with no rashes or lesions. No breast mass is palpable, and there is no axillary lymphadenopathy. Ultrasound did not reveal any masses. What is the most likely diagnosis?
- (A) Fibrocystic changes
 - (B) Intraductal papilloma
 - (C) Ductal carcinoma in situ (DCIS)
 - (D) Paget's disease of the breast
 - (E) Infiltrating ductal carcinoma
12. A 61-year-old female presents with swelling and redness of her entire left breast that has persisted for 4 weeks. On physical exam her temperature is 37.6 °C, pulse is 82/min, blood pressure is 136/78 mmHg, and respirations are 16/min. Her left breast appears larger than her right one. The entire breast is warm, and the skin is edematous. No breast masses are palpable. There is no nipple discharge or rashes. There are several palpable enlarged lymph nodes in her left axilla. Ultrasound and mammography show thickening of the skin but otherwise no masses. Which of the following is the best option for further management?
- (A) Punch biopsy of skin
 - (B) Oral antibiotics
 - (C) Intravenous antibiotics
 - (D) Nonsteroidal anti-inflammatory drug (NSAID)
 - (E) Incision and drainage
13. A 17-year-old female presents with breast pain that she noticed for several months. She states that she feels multiple breast masses in both breasts. She denies any weight loss, fevers, or night sweats. She has no medical history or family history of breast cancer. The skin around the breast and areola are normal with no rashes or lesions. No solitary breast masses are palpable, but both breasts are lumpy and painful to palpation, most notably in the upper outer quadrants. There is no axillary lymphadenopathy. What is the most appropriate next step in management?
- (A) Diagnostic mammography
 - (B) Excisional biopsy
 - (C) Ultrasound-guided core needle biopsy
 - (D) Reassurance and reexamine in 1 month
 - (E) Fine-needle aspiration (FNA)

14. A 57-year-old woman comes to clinic to discuss surgical treatment for a new diagnosis of breast cancer. Her annual screening mammogram revealed a 1.7 cm mass in the right breast. Biopsy of the mass was performed and revealed infiltrating ductal carcinoma. Estrogen receptor and progesterone receptor testing were negative, while HER2 receptor testing was positive. In addition to lumpectomy and breast irradiation, the treating doctor decides to add hormonal therapy with trastuzumab to the treating regimen. What study must be done prior to starting trastuzumab?
- (A) Thyroid stimulating hormone (TSH)
 - (B) Liver function tests
 - (C) Echocardiogram
 - (D) Creatinine clearance
 - (E) Chest X-ray
15. A 25-year-old female lifeguard presents to her doctor to discuss a new 10 mm skin lesion that she found on her right forearm that has been growing over the last month. The lesion has a heterogeneous dark blue color, is symmetric, and has been growing vertically. What is the most likely diagnosis?
- (A) Impetigo
 - (B) Melanoma
 - (C) Nevus
 - (D) Molluscum contagiosum
 - (E) Squamous cell carcinoma
16. Where are melanomas in patients with dark skin most likely to occur?
- (A) Back
 - (B) Arms
 - (C) Legs
 - (D) Palms, soles, and mucous membrane
 - (E) Face
17. A 50-year-old field worker arrives to a free clinic to discuss a "sore" on his lower lip. He has had no trauma to the face. He reports that he first noticed the "sore" 6 months ago, and it has slowly gotten bigger. On physical exam, he has an ulcerated 1 cm nodule on his lower lip. There are no telangiectasias present. What is the most likely diagnosis?
- (A) Basal cell carcinoma
 - (B) Squamous cell carcinoma
 - (C) Lichen planus
 - (D) Dermatitis herpetiformis
 - (E) Melanoma
18. Which of the following melanomas have the best prognosis?
- (A) Superficial spreading
 - (B) Nodular
 - (C) Lentigo maligna
 - (D) Acral lentiginous
 - (E) Subungual
19. Which of the following melanomas do not follow the ABCDE mnemonic?
- (A) Superficial spreading
 - (B) Nodular
 - (C) Amelanotic
 - (D) Acral lentiginous
 - (E) Amelanotic and nodular

20. Which of the following is the most common precancerous skin lesion?
- (A) Actinic keratosis
 - (B) Seborrheic dermatitis
 - (C) Seborrheic keratosis
 - (D) Compound nevi
 - (E) Keratoacanthoma
21. A 45-year-old female presents with a recent change in a preexisting mole on her anterior thigh. She states that the mole keeps bleeding, is darker, and has grown. The mole is 8 mm in diameter on physical exam. There are no palpable nodes in the groin. An excisional biopsy is performed with a 1 mm margin and to a depth of the subcutaneous fat. Pathology reveals a melanoma that is 0.8 mm in thickness with ulceration. The margins are negative. What is the next step in the management?
- (A) No further treatment
 - (B) Re-excision with 1 cm margins
 - (C) Re-excision with 1 cm margins and sentinel lymph node biopsy (SLNB)
 - (D) Granulocyte-macrophage colony-stimulating factor (GM-CSF)
 - (E) Interferon alpha

Answers

1. Answer A
Zinc deficiency can occur in surgical patients on long-term TPN or in patients diagnosed with a malabsorption syndrome. This can present with alopecia, red and inflamed patches of dry and scaly skin around the mouth and eyes, abnormal taste, and impaired wound healing. Zinc supplementation will remedy this condition. Copper and chromium deficiency are rare but can also affect this patient population. The most common manifestations of copper deficiency include hematologic abnormalities (anemia, leukopenia) and myeloneuropathy (B). Chromium deficiency presents with impaired glucose tolerance and peripheral neuropathy (D). Pemphigus vulgaris occurs as a result of autoimmune destruction of desmosomes between keratinocytes and is characterized by multiple skin and oral mucosa bullae (C). Psoriasis is believed to have an autoimmune etiology and presents as salmon-colored plaques with a silvery scale that occur on extensor surfaces (e.g., patella) (E).
2. Answer C
Mohs is a specialized tissue-sparing technique of treating skin cancer in which the tumor is removed in a series of thin layers as opposed to one wide excision. The advantage is that it prevents excising excessive normal tissue and allows for immediate confirmation of negative surgical margins intraoperatively. It is best suited for basal cell and squamous cell carcinoma in cosmetically sensitive areas such as the face. Mohs is not generally recommended for melanoma. This is because it is difficult to distinguish the normal skin from melanoma on frozen section (immunohistochemical stains are sometimes needed). Because of this, Mohs is considered by most surgeons to be an unreliable method of resection for melanoma (A, B, D). The treatment of choice for subungual melanoma is digital amputation.
3. Answer A
A diagnostic mammogram should be ordered in a woman over the age of 30 who presents with a new breast mass. Mammography helps to look for suspicious calcifications in other areas of the affected breast, characterize the mass, as well as evaluate the contralateral breast. It is important to note that the mammogram may be normal despite the presence of a palpable breast cancer. For this reason, a tissue biopsy is recommended for palpable breast masses regardless of the mammogram results. In a

palpable nodule, tissue sampling is best performed via ultrasound-guided core needle biopsy. Ultrasound also provides more information about the mass (cystic vs. solid). FNA is rarely used as it provides only cytology rather than histology (B). MRI would be a useful adjunct in patients with high risk of breast cancer (e.g., BRCA-1) (C). Follow-up examination in 3 months without a biopsy to rule out a malignant lesion would be inappropriate (D). Genetic testing would be indicated if this patient had a strong family history of breast or ovarian cancer but would not be done until tissue diagnosis of breast cancer is confirmed (E).

✓ 4. Answer B

The patient most likely has *mastitis*. This is a localized, painful inflammation of the breast accompanied by fever and malaise usually occurring in breastfeeding women but can affect non-lactating women as well. The diagnosis of mastitis is made clinically based on an erythematous, tender, swollen area of one breast associated with fever. Although this occurs most commonly in nursing mothers, it can also occur in non-nursing women. Other symptoms may include muscle pain (myalgias) and malaise. Transmission occurs via introduction of bacteria in small breaks in the skin caused by the trauma of breastfeeding. Most cases of lactation mastitis are a result of an infection by *Staphylococcus aureus*. Treatment consists of antibiotics to cover skin flora, symptomatic relief with analgesics including anti-inflammatory agents such as ibuprofen, and cold compresses to reduce local pain and swelling. Patients should be encouraged to continue breastfeeding as this helps relieve any ductal obstruction that might be contributing to the infection (C). The breast milk in a woman with mastitis is *not* dangerous to the baby. Biopsy would be appropriate if the patient has suspected inflammatory breast carcinoma (A). Although very rare, inflammatory breast carcinoma can occur during pregnancy. If mastitis fails to resolve after antibiotics, then consideration should be given to performing a biopsy of the skin. At that time, diagnostic mammography should also be ordered (D). Incision and drainage are appropriate if there was evidence of a localized abscess with fluctuance, although more breast surgeons are now recommending needle aspiration to reduce scarring (E). Ultrasound can help differentiate mastitis from a breast abscess.

✓ 5. Answer B

The lesion is concerning for melanoma and as such will require tissue confirmation to rule out cancer. Excisional biopsy (removing the entire lesion), down to the subcutaneous fat, would be the preferred approach for a lesion on an extremity or torso (C). However, depending on the size of the lesion and its location (not desirable to make a cosmetically unappealing large incision if the lesion ends up being benign), an initial incisional biopsy (taking only a small sample) is preferred. Punch biopsy down through the dermis (to calculate Breslow thickness) is the preferred method in this setting. Shave biopsies are not recommended if melanoma is suspected as the true Breslow thickness may not be measurable (A). During the initial biopsy, no attempts are made to achieve a wide margin. If the pathology comes back benign, no further treatment may be necessary. Excisional biopsy with a 5 mm initial margin would not be indicated as the lesion may be benign (D). Reexamination is not appropriate for a patient suspected of having melanoma (E).

✓ 6. Answer C

The most important risk factors for breast cancer are female gender, increasing age, and a family history of premenopausal breast cancer. A new breast mass in a woman over the age of 50 should be considered cancer until proven otherwise, as it carries the highest relative risk of being cancer. A family history of breast cancer can also significantly increase the risk of breast cancer, particularly if diagnosed in a premenopausal woman (B). The majority of inherited breast cancers are associated with BRCA-1 or BRCA-2 gene mutations. Other important risk factors associated with a slightly higher risk of developing breast cancer include early menarche, nulliparity or older age at first full-term pregnancy, and/or late menopause (A, D–E). Increased lifelong exposure to estrogen is common among these risk factors.

- ✓ 7. Answer E
Understanding when to offer surgery, radiation, chemotherapy, hormone therapy, tamoxifen, or SLNB to a breast cancer patient is important, and variations of this question will undoubtedly show up on the surgical shelf exam. There is a formula to answering these questions. First, this patient is diagnosed with infiltrating ductal carcinoma and so should be offered total mastectomy or breast conserving therapy, which consists of lumpectomy *and* radiation. Most elect the latter because it provides better cosmesis. Since this patient has an invasive carcinoma >1 cm, a SLNB is also indicated. If she had DCIS, a SLNB would only be indicated if the lesion was high risk (>5 cm, comedo type, or high grade). Additionally, if she was undergoing total mastectomy (for any size invasive carcinoma or DCIS), a SLNB should be performed as it would *not be possible* to do so at a later time. Hormone receptor (ER/PR)-negative breast cancers are thought to have a worse prognosis as adjuvant hormone therapy is not available. As such, these patients should receive chemotherapy. Similarly, triple-negative breast cancers have an even worse prognosis, and so chemotherapy should be given to these patients as well. Tamoxifen (HER2 receptor blocker) is indicated in patients with HER2-positive breast cancer. In the case of ER/PR-negative but HER2-positive breast cancers, chemotherapy and tamoxifen should be given.
- ✓ 8. Answer A
The presentation is concerning for Paget's disease of the breast. This presents as an eczematous, scaling, and ulcerating lesion around the areola. Paget's disease of the breast is a type of DCIS that extends into the ducts to involve the skin of the nipple. Patients are initially misdiagnosed with a skin condition, including eczema and psoriasis, and receive a variety of ointments that do not resolve the lesion. Paget's disease of the breast is almost always associated with an underlying carcinoma and must be diagnosed via biopsy of the lesion. Trying different regimens of steroids and antibiotics is inappropriate given the high likelihood that she has cancer (B–E).
- ✓ 9. Answer C
The skin lesions described are most likely to be seborrheic keratosis (SK). Isolated SKs occur commonly in the elderly. Sudden onset of multiple SKs (*Leser-Trelat sign*) suggests an underlying carcinoma of the gastrointestinal tract, most often gastric cancer. It is considered to be a result of a paraneoplastic syndrome associated with the cancer. The best next step in working up a suspected GI malignancy is an abdominal CT scan. Given the high likelihood of malignancy, it would be inappropriate to only reexamine the patient in 2 weeks (A). SKs have a characteristic appearance and typically do not need to be confirmed with a skin biopsy (B). Mohs is a specialized tissue-sparing procedure for treating skin cancer (D). It involves tangential excisions of the lesion until margins are negative. Mohs has the advantage in that definitive excision and closure can be achieved on the same day. Corticosteroids are not used in the management of SKs (E).
- ✓ 10. Answer A
DCIS is characterized by malignant epithelial cells within the mammary ductal system, without invasion into the surrounding stroma. Comedo-type DCIS is high grade and associated with a worse prognosis (C). DCIS lesions have a high risk of subsequent invasive carcinoma at the site of the DCIS. As such if left unresected, it will often progress to invasive ductal cancer. Thus, the mainstay of DCIS treatment is breast-conserving therapy (excision of entire lesion with negative margins and radiation). Radiation therapy is used in combination with surgical excision but cannot replace it (E). Lobular carcinoma in situ is considered a marker for malignancy in either breast (B). Breast cancer in males is rare (1% of all breast cancers) with most cases identified as invasive ductal carcinoma. DCIS can occur in men but is even more rare, as DCIS most often presents as abnormal calcifications on mammogram (D).

✓ 11. Answer B

Although bloody nipple discharge should raise concern for cancer, intraductal papilloma is the most common cause of bloody nipple discharge. This is a benign breast tumor arising from the proliferation of mammary duct epithelium that classically occurs in females 20–40 years of age. Treatment includes excision, which is diagnostic as well as curative. Fibrocystic changes are a common cause of breast pain in young females but do not present with bloody discharge (A). Patients report painful breast tissue before menses with improvement during menstruation. Physical exam reveals fibrotic tissue and cystic, lumpy tissue. DCIS and infiltrating ductal carcinoma are more common in older women (C, E). Although breast cancer can present with bloody nipple discharge, it is less common than intraductal papilloma, especially in a young woman. Paget's disease of the breast causes an eczematous lesion on the breast that is associated with an underlying breast carcinoma (D).

✓ 12. Answer A

The patient most likely has inflammatory breast carcinoma, an especially aggressive type of breast cancer. Inflammatory breast cancer can be easily confused with mastitis, as there is usually no palpable breast mass and ultrasound and mammography similarly are *often negative*. As such, it is imperative to perform a biopsy of the skin, which may show cancer cells invading the subdermal lymphatics. Additional workup should include a breast MRI (which is more likely to show the breast cancer in this setting than ultrasound and mammogram), as well as consideration for needle biopsy of the lymph nodes. Antibiotics or NSAIDs would be inappropriate in a patient with high suspicion for cancer (B–D). Incision and drainage would be appropriate if there was an indication on physical examination or evidence of a breast abscess on ultrasound (E). Inflammatory breast carcinoma typically presents as swelling of the breast and with edematous skin due to obstruction of subdermal lymphatics by tumor (termed *peau d'orange*, meaning orange peel in French). At presentation, positive lymph node involvement is frequent, and approximately 1/3 of patients have distant metastases. Inflammatory breast carcinoma can also present during pregnancy and should be suspected if suspected mastitis does not respond to appropriate antibiotic treatment.

✓ 13. Answer D

The history and physical exam are most consistent with a diagnosis of fibrocystic changes of the breast, which is considered a *normal variant* of the breast in adolescents and young adults. Patients will present with painful breast tissue before menses that improves during menstruation. On examination, fibrotic tissue may be palpated and is generally found in the upper outer quadrants of the breast. This patient should be counseled and instructed to look for these changes with a follow-up appointment in a month. Persistent cystic breast lesions can be evaluated and treated with FNA, although this is not needed in children and adolescents (E). Cystic lesions that resolve with aspiration should be reevaluated with ultrasonography 3 months after aspiration, but a core needle biopsy would not be indicated (C). Excisional biopsy is warranted for cystic lesions that do not resolve with aspiration or for suspicious solid lesions (B). Diagnostic mammography is not indicated for adolescents and should be reserved for females >30 years old who present with a breast mass (A).

✓ 14. Answer C

Trastuzumab is a monoclonal antibody that blocks the HER2 receptors. The medication is used in the treatment of HER2-positive breast cancers to help reduce recurrence and improve survival. Since there is a high risk of cardiomyopathy in patients receiving trastuzumab, it is recommended that all patients receive an echocardiogram prior to initiating therapy with trastuzumab. An alternative is to obtain a MUGA scan (multigated acquisition scan), which is a nuclear study that evaluates ventricular function with better fidelity. MUGA scan is considered superior to an echocardiogram but is not

widely available. Trastuzumab-related cardiotoxicity is most often manifested by an asymptomatic decrease in ejection fraction. The optimal surveillance for trastuzumab-related cardiotoxicity is not well defined. The remaining answer choices are not needed prior to starting trastuzumab (A–B, D–E).

✓ 15. Answer B

Nodular-variant melanomas grow vertically, not horizontally. They are usually a uniformly dark blue or black “berry-like” lesion that is mostly symmetric, elevated, and one color. Impetigo is a superficial bacterial infection oftentimes due to *Staphylococcus aureus*. It presents first as a flat macule and then a raised pustule that erodes and oozes a dry, honey-crusted serum (A). A nevus, or a mole, is described as a *small* (<6 mm) macule with sharp, symmetric borders, and an evenly distributed color (C). Molluscum contagiosum is caused by the *poxvirus* and occurs most commonly in children and immunocompromised adults (D). It is characterized by small, firm, pink, and umbilicated papules. Squamous cell carcinoma is a malignant proliferation of epithelial cells that presents as an ulcerated, nodular mass in sun-exposed areas (E).

✓ 16. Answer D

Melanocytes are found in equal numbers in most people (black or white). However, individuals with darker skin have melanocytes that produce more melanin, a protein which makes skin darker and helps protect from skin cancer by absorbing UV-B (B for bad) radiation. As such, in dark-skinned patients, melanomas are more likely to occur in areas that have less pigmentation such as the palms, soles, and mucous membranes (A–C, E). In general, men more commonly have melanoma on the back, while women more commonly have melanoma on the legs.

✓ 17. Answer B

The most common type of lip cancer is squamous cell carcinoma (SCC). Lip cancer occurs much more commonly on the lower lip, as it gets more sun exposure than the upper lip. Occupations that involve long-term sun exposure (e.g., lifeguard, farmer, construction worker, gardener, and field worker) place patients at higher risk for developing skin cancer. SCC is described as an ulcerated, nodular mass without any telangiectasias. Basal cell carcinoma presents as a pearly white nodule with a central ulcerated crater surrounded by dilated vessels (telangiectasias) (A). Lichen planus can be remembered as the “5 Ps:” pruritic, planar, polygonal, purple papules (C). It commonly involves the wrists and elbows and is associated with chronic hepatitis C infection. One of the manifestations of celiac disease includes dermatitis herpetiformis (D). It presents as pruritic vesicles and bullae that are grouped together (herpetiform). It only occurs in a minority of celiac patients and typically resolves with a gluten-free diet. Melanoma presents as a mole-like growth and follows the ABCDE rule (E).

✓ 18. Answer C

Lentigo maligna has the best prognosis of the melanoma subtypes (remember, lentigo is least aggressive). Nodular-variant melanomas are characterized by the absence of a radial growth phase. They are usually a uniformly dark blue or black “berry-like” lesion that is mostly symmetric, elevated, and one color. They are considered to be the most rapidly growing and aggressive variant of malignant melanoma (B). Typically, it arises on apparently normal skin (the head, trunk, and neck are the most common locations) vs. preexisting lesion. Ulceration is common, giving a poorer prognosis. Superficial spreading is the most common type of melanoma (A). It typically has a long horizontal growth phase before the vertical growth phase which confers a better prognosis. Acral lentiginous melanomas are typically found in the subungual, sole or palm location, and common in ethnic groups of color (D–E). Subungual tend to present late as they are often confused with a subungual hematoma.

✓ 19. Answer E

Amelanotic and nodular melanomas do not follow the ABCDE rule (A–D). As previously mentioned, nodular-variant melanomas are characterized by the absence of a radial growth phase. Amelanotic melanomas are notoriously difficult to identify because this variant is deficient in pigment or is unable to produce any pigment at all. For this reason, they typically go unrecognized until the disease advances enough to locally invade the surrounding tissue. Superficial spreading is the most common type of melanoma. It typically has a long horizontal growth phase before the vertical growth phase which confers a better prognosis. Acral lentiginous melanomas are typically found in the subungual, sole or palm location, and common in ethnic groups of color.

✓ 20. Answer A

Actinic keratosis presents as a rough, scaly patch of the skin that can vary in color (pink, red, brown). It is the *most common precancerous skin lesion* and thus can progress to squamous cell carcinoma. Seborrheic dermatitis (cradle cap) is a self-limited condition that commonly affects infants and presents as a yellow, greasy plaque on the scalp (B). Seborrheic keratosis is a common tumor in the elderly and presents as raised, discolored plaques that appear coin-like, waxy, and with a “stuck-on” appearance (C). Both of these conditions are benign and *not considered to be precancerous*. Compound nevi are brown-black, well-circumscribed lesions that are <1 cm in diameter (D). They may be elevated and are frequently hairy, arising from the epidermal-dermal interface and from within the dermis. Malignant transformation is rare. Keratoacanthoma is a low-grade subtype of squamous cell carcinoma that can grow rapidly and become large in size (E). Most will spontaneously get better within a year, but removal with surgery is still recommended.

✓ 21. Answer C

Once the diagnosis of melanoma is established by punch or excisional biopsy, the area needs to be re-excised to obtain wider margins, and in select cases, SLNB is obtained (A). The extent of margins and need for SLNB are determined by tumor thickness. Patients with tumor thickness < 1 mm (considered a thin melanoma) require an excision margin of only 1 cm. Additionally, for tumors <1 mm with ulceration, a SLNB is also performed (B). For melanomas that are thin with no ulceration, SLNB is not performed. Interferon alpha, GM-CSF, and dacarbazine are all adjuvant therapy options for patients with melanoma (D–E). There has been no concrete evidence that adjuvant therapy prolongs survival in melanoma. However, there is some evidence to suggest that there is an improved relapse-free survival and overall survival with high-dose interferon alpha.

Cardiothoracic

Peyman Benharash

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Chest Pain, Diaphoresis, and Nausea

Areg Grigorian, Ryan Ou, Paul N. Frank, and Peyman Benharash

Case Study

A 68-year-old male presents to the emergency room with 4-hours of severe chest discomfort, cold sweats, and nausea. The pain is described as heavy pressure over the entire chest and is 9/10 in intensity. He is mildly short of breath and states that the pain is radiating to his neck. He denies back pain. He has noted reduced exercise tolerance over the past few

months, only being able to walk for ½ block before having to stop to catch his breath. He is able to lie flat without any shortness of breath. He smokes about one pack of cigarettes per day and was recently diagnosed with diabetes mellitus and hypertension. He denies a history of cardiac events or stroke. Physical examination reveals a blood pressure of 144/78 mmHg,

heart rate of 97/min, and a respiration rate of 28/min. Breath sounds are equal without crackles. Cardiac examination reveals a regular rate without murmurs and an S4. An ECG was obtained which shows sinus rhythm with ST segment elevation in V2, V3, and V4. A stat troponin is ordered and returns above normal range. Chest X-ray is normal.

Diagnosis

What Is the Differential Diagnosis?

Table 8.1

Diagnosis	Comments
<i>Aortic dissection</i>	Acute, tearing chest pain radiating to the back, associated with hypertension and Marfan's syndrome, can present with stroke, MI, tamponade, and acute aortic insufficiency; CXR: widened mediastinum
<i>Acute coronary syndrome</i>	Includes STEMI, NSTEMI, and unstable angina; chest pain described as an "elephant on chest," with shortness of breath, diaphoresis, nausea, vomiting, tachycardia, and hypotension
<i>Coronary vasospasm</i>	Common in younger patients, cocaine users, and women; coronary narrowing caused by autonomic dysfunction and mimics typical angina associated with a true myocardial infarction
<i>Pericarditis</i>	Pleuritic chest pain that improves with leaning forward, dyspnea, cough, fever, friction rub, pulsus paradoxus (drop in blood pressure on inspiration) if tamponade present
<i>Pulmonary embolism</i>	Pleuritic chest pain (i.e., worse with inspiration), marked dyspnea, hypoxia, hypotension if embolus is massive; right heart strain and abnormal ECG findings may be present
<i>Diffuse esophageal spasm</i>	Esophageal motility disorder presenting with chest pain, dysphagia, and food regurgitation; may be triggered by reflux, caffeine, and spicy foods
<i>Esophageal perforation</i>	Most commonly after invasive procedures such as endoscopy; also in alcoholics with forceful vomiting (i.e., Boerhaave syndrome)
<i>Spontaneous Pneumothorax</i>	Collapsed lung in tall, thin patients, may present as acute pain and shortness of breath
<i>MI myocardial infarction, STEMI ST-elevated myocardial infarction, NSTEMI non-ST-elevated myocardial infarction, CXR chest x-ray</i>	

What Is the Most Likely Diagnosis?

Given the patient's history of severe chest pain with radiation to the neck, reduced exercise tolerance, and ST elevation in leads V2, V3, and V4, the patient is likely suffering from an acute coronary syndrome, specifically a STEMI secondary to an occluded left anterior descending coronary artery.

Watch Out

Aortic dissection can cause acute coronary artery occlusion and can present in a similar fashion; however, we might also expect a diastolic murmur from aortic regurgitation and a widened mediastinum on chest X-ray.

History and Physical

What Are the Risk Factors for Myocardial Infarction (MI)?

Increased age, male, hypertension, hypercholesterolemia, diabetes, smoking, and family history of coronary artery disease are the risk factors for myocardial infarction.

What Elements on the History and Physical Exam Make MI Less Likely in a Patient Presenting with Chest Pain?

Patients under the age of 40 with no cardiovascular risk factors and older healthy patients (e.g., 60-year-old swimmer) with no cardiovascular risk factors are highly unlikely to be having an MI. Pain that is reproducible by palpation is more suggestive of musculoskeletal pain. Localized pain that is described as being sharp is also less likely to be related to heart disease, as is chest pain related to eating in general or eating certain foods.

What Are the Classic History and Physical Exam Findings Seen in MI?

Chest pain, diaphoresis, anxiety, tachycardia, tachypnea, and nausea/vomiting are classic findings. If there is a large area of ischemic damage to the heart, the patient may have heart failure presenting with bilateral rales (pulmonary edema), jugular venous distention, new S3 or S4 heart sounds, new murmurs, and hemodynamic instability (i.e., cardiogenic shock).

What Group of Women Is at Highest Risk for MI? Why?

Postmenopausal women are at higher risk for MI. In fact, heart disease is the leading cause of death in women over the age of 40. The decline in estrogen levels is believed to contribute to a higher cardiovascular disease risk profile. Estrogen promotes growth and maintenance of the intimal layer of the arterial wall, maintaining its ability to expand and accommodate blood flow. However, exogenous estrogen

supplementation has not reduced the cardiovascular risk in women.

Watch Out

Women presenting with MI are more likely than men to have atypical, vague symptoms.

What Are the Three Classic Symptoms of Aortic Stenosis?

The three classic symptoms of aortic stenosis are angina, syncope, and congestive heart failure. High myocardial wall tension coupled with left ventricular hypertrophy increases myocardial oxygen demand which is further compromised by decreased diastolic coronary blood flow. This combination of events can result in angina later in the course of the disease. The thickened ventricular cavity that may also be somewhat ischemic leads to a stiff ventricle that requires higher filling pressures to maintain end-diastolic volume. This in turn leads to increased pulmonary venous pressures and sensation of dyspnea.

What Are the Differentiating Features of Various Cardiac Murmurs?

Table 8.2

Murmur	Description	Location
<i>Aortic stenosis</i>	Mid-systolic crescendo-decrescendo	Upper right sternal border
<i>Aortic regurgitation</i>	Decrescendo diastolic murmur	Lower left sternal border
<i>Mitral stenosis</i>	Diastolic opening snap, low-pitched diastolic murmur, as stenosis worsens, the opening snap occurs earlier in diastole	Apex
<i>Mitral regurgitation</i>	Holosystolic murmur, decreased or absent S1	Apex, radiating to axilla
<i>Mitral valve prolapse (MVP)</i>	Mid/late systolic click, possibly followed by late systolic crescendo-decrescendo murmur	Apex
<i>Hypertrophic obstructive cardiomyopathy (HOCM)</i>	Systolic crescendo-decrescendo murmur	Upper left sternal border

Changes Seen in Systolic Murmurs with Various Maneuvers

Table 8.3

	Valsalva (decreases preload)	Handgrip (increases afterload)	Leg raise (increases preload)
<i>Aortic stenosis</i>	↓	↓	↑
<i>Hypertrophic cardiomyopathy</i>	↑	↓	↓
<i>Mitral regurgitation</i>	↓	↑	↑
<i>Ventricular septal defect</i>	↓	↑	↑

Pathophysiology

What Is Meant by Acute Coronary Syndrome?

Acute coronary syndrome entails varying degrees of acute myocardial ischemia, the end result of coronary artery disease. There are three types of acute coronary syndrome: unstable angina (UA), non-ST segment elevation myocardial infarction (NSTEMI), and ST segment elevation myocardial infarction (STEMI).

What Is the Difference Between UA, NSTEMI, and STEMI?

Table 8.4

Condition	Comments
UA	Nonocclusive thrombosis causes reduced myocardial perfusion, but no myonecrosis (death of cardiac myocytes), hence no elevation in cardiac enzymes
NSTEMI	Occlusive thrombosis eliminates perfusion to only partial thickness of the myocardial wall (affects the subendocardial side) and causes myonecrosis leading to elevation in cardiac enzymes and possibly ECG findings suggestive of ischemia (but not ST segment elevation)
STEMI	Occlusive thrombosis eliminates perfusion to full thickness of the myocardial wall and causes myonecrosis leading to elevation in cardiac enzymes and characteristic elevation of ST segment on ECG

What Are the Series of Events that Take Place During an Acute Myocardial Infarction?

Thrombus formation following plaque rupture is the primary mechanism involved in coronary vessel obstruction leading to ischemia and, eventually, myocyte necrosis and tissue death.

What Coronary Vessel Is Most Often Affected?

The left anterior descending (LAD) artery is the most commonly affected coronary vessel.

Are There Different Mechanisms of Myocardial Infarction?

Yes. MIs are classified based on whether or not there is a primary coronary event, such as a plaque rupture with subsequent thrombosis. Causes of MI not associated with

a primary cardiac event include decreased oxygen supply (e.g., hypoxia, hypotension, anemia) and increased myocardial oxygen demand (e.g., sepsis, tachyarrhythmias). Postoperative MIs often result from a combination of factors other than primary coronary events. Primary coronary events require urgent intervention, while MIs resulting from non-primary coronary events will often resolve as the underlying cause is addressed.

What Is Suggested by Episodic Chest Pain Unrelated to Exertion in a Young Person?

Prinzmetal (vasospastic) angina is characterized by episodic chest pain unrelated to exertion. Coronary artery vasospasms are responsible for transient decreased perfusion to the heart which causes reversible injury to myocytes. ECG shows ST segment elevation secondary to transmural ischemia, similar to what is seen in unstable angina. However, Prinzmetal angina is not due to coronary artery disease.

What Is the Dreaded Consequence of Aortic Stenosis?

Patients with aortic stenosis are at increased risk of sudden death. This risk is about 2% in asymptomatic individuals and up to 34% of symptomatic individuals. While the mechanism is not agreed upon, it has been hypothesized that ventricular arrhythmias or an abnormal baroreceptor reflex may be contributing factors. Sudden death can occur during anesthetic induction, so it is essential that the aortic stenosis murmur be recognized by preoperative physical examination prior to any surgical procedure.

Workup

What Are the Initial Diagnostic Steps for Suspected Myocardial Infarction?

In addition to a relevant history (i.e., prior MI, chest pain) and physical exam, the patient should have a 12-lead ECG and a blood test for cardiac enzymes. A chest radiograph will help rule out other diagnoses like pneumothorax and aortic dissection.

What Is the Role of Measurement of Cardiac Enzyme Levels in the Blood?

Cardiac enzymes (Table 8.5), including troponin-I and creatine phosphokinase myocardial fraction (CKMB), are measured every 8 hours in the first 24 hours of a suspected MI. CKMB is the first to rise, but it has a low specificity. Troponin-I has the highest sensitivity for MI and increases in 3 hours, peaks in 6 hours, and gradually decreases over 7 days.

Table 8.5 Coronary anatomy and ECG changes

Biomarker	Interpretation
<i>Troponin</i>	Elevated levels of troponin correlate with increased risk of death and other adverse outcomes; indicates death of cardiac myocytes; cardiac troponin is more sensitive than CKMB
<i>CKMB</i>	Elevated level indicates death of cardiac myocytes
<i>BNP</i>	Released by ventricular myocytes in response to increased stretch, as in CHF
<i>D-dimer</i>	Byproduct of fibrin breakdown; elevated levels very nonspecific but may indicate blood clot formation

Watch Out

Ischemia causing death of cardiac myocytes can cause elevation in cardiac enzymes in both NSTEMI and STEMI, but not in unstable angina.

What Is the Best Cardiac Enzyme to Diagnose a Second MI on Top of a Recent MI?

CKMB is the best marker to look for secondary MI following a recent MI. Its levels peak within 12–40 hours following MI and decrease after 2–3 days. Therefore, in a subsequent MI, there will be a new increase in CKMB.

Watch Out

Both CKMB and troponin are cleared through the kidneys and may have a much longer half-life in the presence of kidney disease.

What Is the Role of ECG?

ECG will help determine whether there is actually ischemia or infarction and, if so, the location of the ischemia or infarction (Table 8.6). ECG may potentially identify nonischemic causes of the patient's symptoms, such as pericarditis, pulmonary embolism, and arrhythmia.

What Is the Role of Imaging?

Imaging has a limited role in the setting of suspected acute coronary syndrome, as time is of essence in establishing coronary reperfusion, unless other diagnoses are suspected. If the chest pain is atypical for MI (e.g., ripping, tearing), a chest X-ray should be obtained to rule out other causes of

Table 8.6 Coronary anatomy and ECG changes

Coronary artery	Branch of	Supplies	ECG leads changes
<i>Left anterior descending (LAD) artery</i>	Left coronary artery	Anterior wall of left ventricle, anterior 2/3 of intraventricular septum	V2, V3, V4
<i>Circumflex branch</i>	Left coronary artery	Lateral and posterior wall of left ventricle, left atrium	aVL, V5, V6
<i>Posterior descending artery</i>	Right coronary artery (80% of patients)	Inferior wall of left ventricle, posterior 1/3 of intraventricular septum	II, III, aVF

chest pain such as aortic dissection. Echocardiography can also be obtained to examine wall motion abnormalities when diagnosis is uncertain. However, this should not delay reperfusion therapy as that is key to improving outcomes of STEMI.

Management

What is the Initial Management of STEMI?

Table 8.7

Intervention	Rationale
Aspirin	Inhibits platelet aggregation; given before PCI or fibrinolysis
Clopidogrel	Inhibits platelet aggregation; given before PCI or fibrinolysis
Platelet glycoprotein IIb/IIIa antagonist	Inhibits platelet aggregation; given before PCI
Heparin	Prevent clot formation; given before PCI or fibrinolysis
β -blocker	Alleviates chest pain by reducing heart rate and contractility (reduces oxygen demand); may also prevent reinfarction and ventricular fibrillation; not given to patients with evidence of cardiogenic shock
Nitroglycerin	Alleviates chest pain by causing vasodilation, thereby reducing preload and afterload (reduces oxygen demand) and improving myocardial perfusion (increases oxygen supply); may cause hypotension

(continued)

Table 8.7 (continued)

Intervention	Rationale
Morphine	Alleviates chest pain by stimulating opioid receptors; only given if chest pain persists despite 3 doses of sublingual nitroglycerin; may cause hypotension or heart block
ACE inhibitor	Especially for patients with anterior MI and EF <40%; reduces fatal and nonfatal cardiac events; also prevents cardiac remodeling
Angiotensin receptor blocker (ARB)	For patients who cannot tolerate ACE inhibitor (e.g., cough)
Atorvastatin	Reduces ischemic complications and expedites resolution of ST segment elevation in patients undergoing PCI; reduces LDL level; recommended for all patients with STEMI unless contraindication to statin therapy (e.g., liver disease)
Supplemental oxygen	Only in patients with low oxygen saturation
PCI percutaneous coronary intervention	

When Should Nitrates Be Avoided?

Nitroglycerin is useful in patients with persistent chest pain; however it should be used with caution or even avoided in patients with right ventricular infarcts or severe aortic stenosis as it can precipitate hypotension and further reduce coronary blood flow. In addition, nitrates are contraindicated in patients who have taken a phosphodiesterase inhibitor (i.e., for erectile dysfunction or pulmonary hypertension) in the last 24 hours.

Watch Out

The most concerning symptom in patients with aortic stenosis is dyspnea, since half of these patients with evidence of CHF will succumb to the disease within 2 years without surgical valve replacement.

What Options for Reperfusion Are Available for STEMI?

The preferred treatment is thrombolysis and stenting in the catheterization lab, known as percutaneous coronary intervention (PCI), within 90 min of symptom onset. In the catheterization lab, the clot can be extracted and the lesion stented with either bare metal or drug-eluting stents. If the patient cannot undergo catheterization within 90 min, systemic thrombolysis via intravenous tPA should be given.

What if PCI Is Unsuccessful?

If adequate flow cannot be established using percutaneous techniques in the catheterization laboratory, the patient may be referred for emergency coronary artery bypass grafting (CABG). Emergency operations for STEMI continue to have a high mortality despite many technological advances in myocardial protection.

Does the Timing of Intervention Matter?

Yes. Classically, revascularization of the myocardium within 90 min is recommended for optimal recovery. Some studies have shown that revascularization can be effective for up to 6 hours, but with diminishing benefits.

What Is the Initial Management of NSTEMI?

As with STEMI, patients with NSTEMI should receive aspirin, β -blocker, nitroglycerin, heparin, platelet glycoprotein IIb/IIIa receptor antagonist (e.g., eptifibatide), supplemental oxygen (for hypoxic patients), morphine (if nitroglycerin does not relieve pain), and ACE inhibitor.

What Are the Next Options in the Management of NSTEMI?

Patients with an NSTEMI do not need urgent percutaneous coronary intervention (PCI) unless one of the following conditions is met:

- Recurrent angina at rest or with minimal exertion
- Evidence of CHF (e.g., S3 gallop, pulmonary edema)
- High-risk findings on stress testing
- Left ventricular ejection fraction <40%
- Hemodynamic instability (i.e., hypotension)
- Sustained ventricular tachycardia
- PCI within the past 6 months
- Prior CABG

Patients without the above conditions may be treated medically and observed, with follow-up echocardiogram and stress test.

What Is the Most Important Determinant of Long-Term Outcome After STEMI? Is there a role of emergency CABG after a STEMI?

The most important determinant is the speed at which blood flow is restored to the ischemic myocardium. In most cases, fibrinolysis or percutaneous intervention would be able to accomplish this much faster than CABG, largely attributable to delays in getting the patient to the operating room. Indications for CABG after STEMI include failed PCI, cardiogenic shock, and free rupture.

What Are the Indications for CABG in the Elective Setting?

CABG is rarely performed in the emergent setting (<5% of cases). In the elective setting, this procedure is reserved for stable patients with the following conditions:

- >50% stenosis of the left main coronary artery
- >70% stenosis in three major coronary arteries
- Stenosis of the proximal left anterior descending artery and one other artery
- Stenosis of one or more coronary arteries with unacceptable angina despite medical management
- Obstructions not amenable to stenting (e.g., at bifurcations)

What Does the Traditional Coronary Artery Bypass Grafting (CABG) Entail?

Traditional CABG involves performing a median sternotomy and placing the patient on a heart-lung machine (pump) while the heart is temporarily arrested. The ascending aorta is clamped, and then a cold solution high in potassium is administered into the aortic root to induce cardiac arrest and help protect the heart while vascular grafts are placed. The coronary artery blockages are bypassed using various grafts, including the internal mammary artery, greater saphenous vein, radial artery, and even the gastroepiploic artery.

What Is the Best Conduit for CABG?

The internal mammary artery, a branch of the subclavian artery, is the best conduit for CABG. Greater than 95% of these bypasses to the LAD are patent at 10 years. This bypass is referred to as a left internal mammary artery (LIMA) to LAD.

Should More than One Coronary Artery Be Bypassed During CABG?

Several studies have suggested that long-term survival is superior in patients receiving two or more coronary bypass grafts, compared to patients receiving only one. In addition, the rates of postoperative cardiac events (e.g., angina, MI, graft occlusion, or PCI) and death are also lower in patients receiving multiple grafts.

How Does CABG Compare to Coronary Artery Stenting in Patients with Multivessel Coronary Artery Disease?

Despite the improvement in stent technology (drug-eluting stents), CABG continues to be superior to stenting in terms of lower rates of mortality, MI, and revascularization and thus remains the standard for multivessel disease.

What Medical Interventions Are Associated with Improved CABG Outcomes in the Perioperative Period?

Aspirin, beta-blockers, statin therapy, and antibacterial prophylaxis for postoperative infections are associated with improved CABG outcomes in the perioperative period.

Watch Out

Clopidogrel or other similar thienopyridine category drugs should be discontinued before CABG.

What Are the Predictors of Mortality Following CABG?

Preoperative cardiogenic shock, emergent surgery, age >65, and depressed left ventricular ejection fraction.

How Is Prinzmetal Angina Managed?

Since the etiology of the chest pain is due to transient coronary vasospasms, calcium channel blockers are typically used to treat the underlying cause, while nitroglycerin is used to rapidly decrease the chest pain.

Complications

What Are the Complications of MI?

Table 8.8

Complication	Characteristics	Post-MI timing
<i>Cardiogenic shock</i>	Large ischemic areas and tissue death may compromise the contractility of the heart preventing adequate cardiac output; most common cause of death while hospitalized	Immediate
<i>Congestive heart failure</i>	Characterized by a decreased ejection fraction, can progress to cardiogenic shock	Immediate
<i>Arrhythmia</i>	90% of patients develop some form of arrhythmia in the post-MI state with ventricular fibrillation being the most deadly; most common cause of death outside the hospital	First 2 days
<i>Pericarditis</i>	Pleuritic chest pain that decreases with leaning forward, dyspnea, cough, fever, friction rub	2–4 days

(continued)

Table 8.8 (continued)

Complication	Characteristics	Post-MI timing
<i>Cardiac tamponade</i>	Rupture of the ventricular wall may lead to tamponade; may present with Beck's triad of hypotension, distended neck veins, and muffled heart sounds on auscultation	2–10 days
<i>Rupture</i>	Immune cells have removed debris of dead cells, thereby weakening the affected region; interventricular septal rupture can cause left to right shunt; free wall rupture can cause pericardial tamponade; papillary muscle rupture can cause acute mitral regurgitation	3–7 days
<i>Ventricular aneurysm</i>	Occur as a result of a weakened ventricular wall; can lead to stroke (mural thrombus forms which can embolize), heart failure, arrhythmias	5–90 days
<i>Dressler's syndrome</i>	Autoimmune condition where antibodies form against the pericardium and result in an inflammatory pericarditis	1 month

Areas You Can Get in Trouble

Silent MI

In up to 25% of cases, patients may experience silent or atypical MIs in which they do not present with the classic symptoms associated with MI including chest pain. This most often occurs in women, elderly, and diabetic patients.

Misdiagnosing Aortic Dissection as Acute MI

An aortic dissection may cause severe chest pain mimicking an MI. Patients are often evaluated for a heart attack only to be subsequently found to have an aortic dissection. A Stanford type A aortic dissection (i.e., involving the ascending aorta) can cause coronary artery occlusion and acute MI, as well as heart failure due to acute aortic regurgitation.

Area of Controversy

Is the Radial Artery Useful as a Graft in CABG?

There has been an increased use of the radial artery in recent years, particularly for patients that do not have a viable IMA or saphenous vein available. The long-term comparisons with

vein graft have demonstrated variable outcomes. However, a recent study suggests radial artery may even be superior to saphenous vein. On the contrary, some surgeons argue that radial arteries do not dilate well due to their muscular nature.

Summary of Essentials

History and Physical

- Increased age, male gender, cardiovascular disease, diabetes, and smoking are all risk factors for MI
- Chest pain, diaphoresis, anxiety, tachycardia, tachypnea, and nausea/vomiting

Pathophysiology

- Acute coronary syndrome
 - UA, NSTEMI, and STEMI
- Thrombus formation following plaque rupture is the primary mechanism involved in coronary vessel obstruction leading to ischemia
- LAD most commonly affected
 - Supplies anterior wall of the left ventricle and anterior 2/3 of intraventricular septum
 - ECG changes in leads V2, V3, and V4

Workup

- Workup of MI must be quick
- Timing of revascularization is critical
 - Ideally within 90 min of symptom onset
 - Some benefit up to 6 hours after onset
- ECG
- Cardiac enzymes q8 hours × 24 hours
 - Troponin-I
 - CKMB
- CXR
 - Rule out aortic dissection
- Echocardiogram (if definitive management not delayed) for wall motion abnormalities, ejection fraction
- Determine if STEMI or NSTEMI

Management

- Initial management
 - Combination of aspirin, clopidogrel, platelet glycoprotein IIb/IIIa antagonist, heparin, β -blocker, nitroglycerin, statin, and morphine
- STEMI
 - Catheterization suite within 90 min for PCI
 - Systemic thrombolysis if PCI not immediately available
- NSTEMI
 - Most do not require PCI

- Limited subendocardial oxygen supply-demand mismatch allows for more conservative management
- Medical management and elective cardiac catheterization on a selective basis
- CABG
 - Urgent/emergent (rare)
- Cardiogenic shock
- Failed PCI
- Presenting >12 hours after of the initial insult
 - Elective
- Left main coronary artery disease
- Multivessel disease of other coronaries
- Failed PCI or not amenable to PCI
 - IMA preferred conduit combined with RSVG
 - Most performed with heart-lung machine
 - Better long-term survival than stenting for multivessel disease

Suggested Reading

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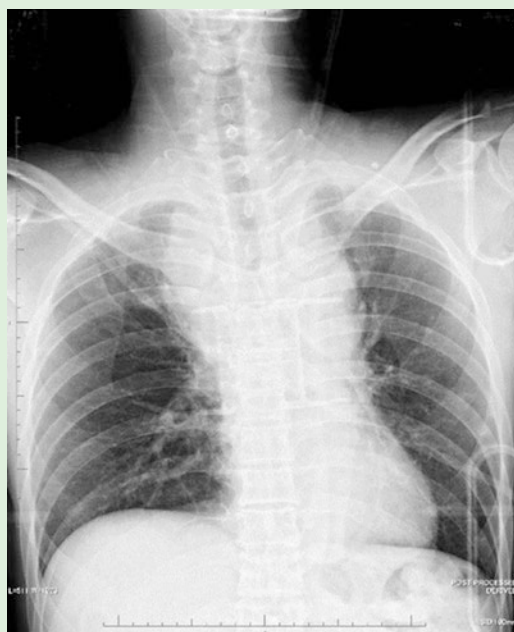


Chest and Back Pain

Ryan Ou, Paul N. Frank, and Peyman Benharash

Case Study

A 26-year-old male presents to the emergency department complaining of sudden-onset severe chest pain radiating to the upper back for the past 3 hours. He describes it as a tearing sensation in his back. He denies any fevers or chills but reports an episode of syncope prior to arriving to the hospital. He is unable to remain still secondary to pain. His past medical history is negative. On initial exam, his blood pressure is 140/50 mmHg, and heart rate is 102/min. He appears to be tall and thin, with long arms, long thin fingers, and hypermobile joints. His sternum has a concave deformity. Cardiac examination reveals a regular rhythm with an early diastolic murmur at the left upper sternal border and muffled heart sounds. Breath sounds are equal bilaterally without crackles. ECG demonstrates nonspecific ST-segment changes. Troponin and CK-MB are within normal ranges. A chest x-ray demonstrates a widened mediastinum (■ Fig. 9.1).



■ Fig. 9.1 Chest radiograph on admission showing widening of the upper mediastinum

9

Diagnosis

What Is the Differential Diagnosis?

■ Table 9.1

Condition	History and physical
<i>Aortic dissection</i>	Sudden onset of tearing chest pain radiating to the back or scapula, syncope, hypertension, connective tissue disorders (e.g., Marfan's syndrome)
<i>Aortic regurgitation</i>	Diastolic murmur loudest at upper right sternal border with increased pulse pressure; may occur acutely with aortic dissection or endocarditis
<i>Endocarditis</i>	History of rheumatic heart disease, congenital anomalies (e.g., mitral valve prolapse), or IV drug use; fever, new murmur, positive blood cultures, Janeway lesions (nontender lesions on palms and soles), and Osler nodes (tender lesions on digits)
<i>Cardiac arrhythmia</i>	Unprovoked syncope, dizziness, and hypotension
<i>Acute pericarditis</i>	Substernal, pleuritic chest pain, worse supine, better leaning forward, fever, tachycardia, friction rub, pulsus paradoxus
<i>Unstable angina</i>	Episodic chest pain of cardiac origin that occurs at rest; may be relieved with nitroglycerin
<i>Non-cardiac causes of chest pain</i>	Pulmonary (e.g., pulmonary embolus, pneumonia, pneumothorax), GI (e.g., esophageal spasm, GERD, Boerhaave syndrome), pancreatitis

GERD gastroesophageal reflux disease, GI gastrointestinal

What Is the Most Likely Diagnosis?

Ascending aortic dissection secondary to Marfan's syndrome. The history is classic for an aortic dissection. Additionally, the history and physical exam suggest the patient has suffered complications secondary to the aortic dissection including acute aortic insufficiency (early diastolic murmur and increased pulse pressure) and pericardial effusion (muffled heart sounds). It is also suggestive from the presentation that this patient has Marfan's syndrome. These patients are typically tall, thin, and can have cardiac, skeletal (pectus excavatum, arachnodactyly, hyperflexible joints), and/or ocular (ectopic lentis: displacement of the crystalline lens) abnormalities. It is important to rapidly establish the diagnosis of aortic dissection and to determine the dissection type (Stanford A or B), as the management of a dissection is dramatically different from other diagnoses and the management of types A and B also greatly differs (discussed further below).

History and Physical

What Are the Risk Factors for Aortic Dissection?

The risk factors for aortic dissection are hypertension, connective tissue disease (e.g., Marfan's, Ehlers-Danlos), advanced age, atherosclerosis, pregnancy, cocaine use, aortic injury (e.g., trauma, cardiac catheterization, bicuspid aortic valve), and aortic coarctation.

Watch Out

Systemic hypertension is the most commonly identified risk factor for aortic dissection.

What Is the Significance of Unequal Pulses in the Upper and Lower Extremities in Patients with Aortic Dissection?

Unequal pulses suggest that the blood supply to one of those extremities is adversely affected and therefore provides a clue as to the location of the dissection. An upper extremity pulse discrepancy is consistent with a dissection involving the aortic arch, whereas a lower extremity pulse discrepancy suggests involvement of the descending aorta all the way down to the iliac arteries.

What Is the Significance of an Increased Pulse Pressure?

Patients with aortic insufficiency will present with a widened pulse pressure (as in this patient). Diastolic pressure decreases due to regurgitation, while systolic pressure increases secondary to the increased stroke volume as a result of the backflow of the blood from the aorta (increased preload).

What Is the Significance of New Diastolic Murmur?

Aortic insufficiency, as evidenced by a new diastolic murmur, occurs in 50–75% of ascending (Stanford type A) aortic dissection cases. Aortic valve incompetence is usually due to annular dilation or cusp prolapse resulting from the detachment of leaflets from the aortic wall. This can be due to dilation of the annulus, such that the leaflets cannot coapt, or extension of the dissection into the aortic root, resulting in detachment of the leaflets.

What Is the Significance of a History of Intravenous Drug Abuse (IVDA)?

Patients with IV drug use are at risk for endocarditis due to introduction of bacteria into the blood stream. Endocarditis often presents with fever and valvular regurgitation. Classic physical findings for endocarditis are listed in [Table 9.2](#).

Table 9.2

Finding	Pathophysiology
<i>Petechiae</i>	Septic emboli or vasculitic processes
<i>Splinter hemorrhages</i>	Microscopic blood clots underneath the nail
<i>Osler nodes</i>	Septic emboli to small vessels in the skin causing <i>tender</i> microabscesses
<i>Janeway lesions</i>	Small erythematous or hemorrhagic <i>nontender</i> lesions on the palms, soles, or distal finger pads
<i>Roth spots (retinitis septica)</i>	Retinal hemorrhages, white spot close to the optic disk surrounded by hemorrhage

Pathophysiology

What Is the Initial Event Leading to an Aortic Dissection?

An aortic dissection is a progressive separation of the aortic wall that results from a tear in the intima that progresses into the media, essentially splitting the aorta into an inner layer of intima and inner media and an outer layer of outer media and adventitia. This produces two lumens: a true lumen and a false lumen. The true lumen is where the blood normally usually flows, while the false lumen is a new channel that is formed between the intimal flap and the outer media. As blood flows into the false lumen, the tear propagates and the false lumen enlarges. Eventually secondary tears may develop, which allow the blood to reenter the true lumen. The tear is a direct consequence of aortic wall shear stress and most often happens in areas exposed to high mechanical forces (such as the aortic arch and proximal descending aorta just distal to the left subclavian artery).

Why Are Patients with Marfan's Syndrome at Increased Risk for Aortic Dissection?

Marfan's is a connective tissue disease that has an autosomal dominant mode of transmission. The primary defect involves the misfolding of fibrillin proteins, resulting in cystic medial necrosis of large vessels such as the aorta. The subsequently weakened medial wall is left susceptible to dissection. This can also happen in other connective tissue disorders such as Ehlers-Danlos syndromes. These patients should avoid weight lifting (as it markedly elevates blood pressure) and contact sports.

Are Dissections and Aneurysms the Same Disease?

No. An aneurysm is a dilation (mostly fusiform) of all three layers of an artery that may progressively enlarge. Patients with Marfan's are at risk for both aneurysm (mainly in the aortic root) and dissection. Confusion arises in that an ascending aortic aneurysm increases the risk of dissection, and dissection weakens the arterial wall, such that the lumens (both true and false) dilate over time so that a chronic aortic dissection appears aneurysmal.

How Are Aortic Dissections Classified?

Two traditional classification schemes exist (DeBakey and Stanford), both of which describe dissections based on the segments of the aorta involved (■ Fig. 9.2). A Stanford type A dissection involves the ascending aorta/aortic arch, whereas a type B does not. A Stanford type B dissection begins in the descending aorta, distal to the takeoff of the left subclavian artery. The main disadvantage of the Stanford classification is that it does not distinguish between patients with isolated ascending aorta/aortic arch dissection and patients with dissection involving the entire aorta. However, since the most important determinant of therapy is whether the ascending aorta/aortic arch is (Stanford A) or is not (Stanford B) involved, the Stanford classification is more commonly used. Remember, Type A is Anything Involving Ascending.

Watch Out

Stanford type B aortic dissections are the most common type overall. However, Marfan's patients more often present with type A aortic dissections.

How Do Aortic Dissections Cause Complications?

The complications and subsequent clinical presentation are highly dependent on the anatomic location of the dissection and whether the dissection affects major arterial branches (■ Table 9.3). The expanding false lumen can interfere with blood flow in the true lumen and compromise perfusion of branch vessels, such as those supplying the liver, mesentery, kidneys, or limbs. This is known as malperfusion syndrome.

What Life-Threatening Complications Are Specific to Dissections that Involve the Ascending Aorta/Aortic Arch (Stanford Type A)?

Type A dissections may dissect into and obstruct blood flow in the coronary arteries, causing myocardial infarction (MI). They may also disrupt blood flow in the carotid arteries, which can cause ischemic stroke. They may also dissect into the pericardial sac, causing acute tamponade, and dissect the aortic valve, leading to acute aortic insufficiency.

What Major Complications Are Specific to Dissections that Only Involve the Descending Aorta (Stanford Type B)?

Type B dissections are much less likely to cause acute complications since the ascending aorta/aortic arch is not involved. Since they begin distal to the left subclavian artery and since the descending thoracic aorta does not have any major arterial branches (other than sometimes to the spinal cord), the

■ **Fig. 9.2** Aortic dissection classification scheme diagram. (Illustration by Anne-Sophie Sillesen; From: Pandey VA, Hamady M (2012) Aortic dissection. In: Hoballah J, Lumsden A (eds) *Vascular surgery*. New Techniques in Surgery Series, vol 6. Springer, London. Reprinted with permission)

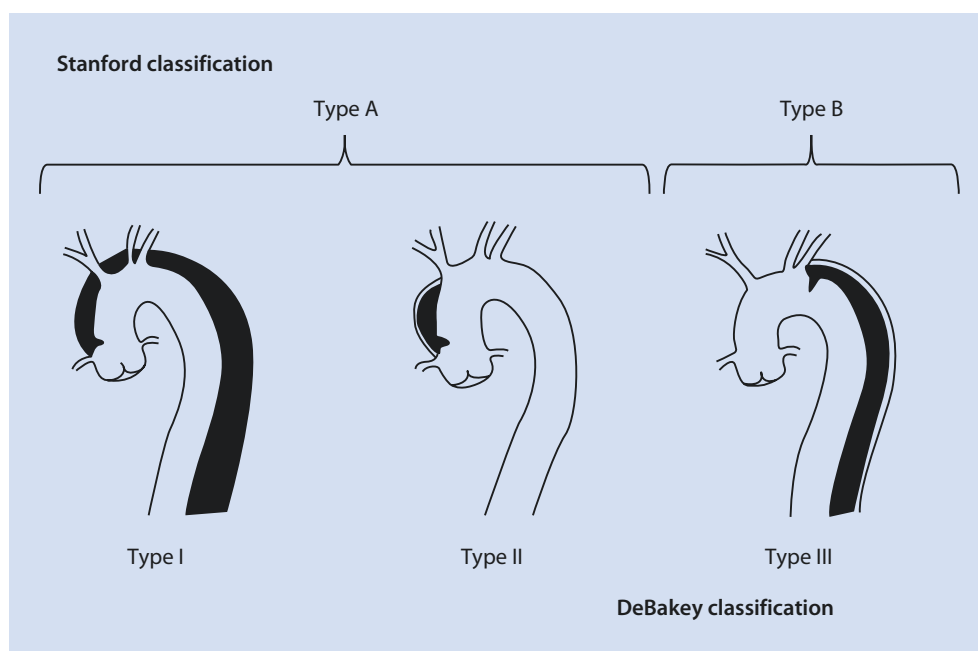


Table 9.3 Malperfusion syndrome: complications during aortic dissection

Complication	Branching artery	Comments
Type A dissection		
Cardiac ischemia	Coronary	Angina, nausea, vomiting, elevated cardiac enzymes; often involving the RCA
Cerebral ischemia	Brachiocephalic or carotid	May lead to stroke
Type A or type B dissection		
Paraplegia	Intercostal or lumbar (Artery of Adamkiewicz)	Ischemia of the spinal cord can result in loss of motor function in the lower extremities
Mesenteric ischemia	SMA	Abdominal pain “out of proportion” to physical exam, nausea, bloody diarrhea in severe cases
Kidney failure	Renal	Oliguria, elevated BUN, creatinine
Limb ischemia	Subclavian or iliac artery	Pain, pallor, and pulselessness in the extremities

SMA superior mesenteric artery, RCA right coronary artery

dissection can extend for a long distance without causing malperfusion. Note that type A dissections can extend into the descending aorta and have similar manifestations.

Workup

What Laboratory Tests Should Be Ordered Immediately?

Although laboratory studies are often of little value in working up aortic dissection, most clinicians will order blood typing and crossmatching, cardiac biomarkers (e.g., troponin, CK-MB), and ECG. Note that elevated cardiac markers and ST changes on ECG cannot rule out an aortic dissection since acute coronary syndrome is one of the possible sequelae of aortic dissection.

What Is the First Imaging Modality Recommended in a Patient Who Presents with Acute Chest Pain?

Chest x-ray should be obtained as it will demonstrate a widened mediastinum in most patients with dissection. However, 15–20% of patients will have a normal chest x-ray. If the chest x-ray shows a widened mediastinum or if suspicion for dissection remains high based on history and physical exam, then a chest CT with intravenous contrast should be obtained next.



Fig. 9.3 Axial CT showing a Stanford type A aortic dissection involving the ascending and descending aorta. White arrows: intimal flap. Black arrow: true lumen



Fig. 9.4 Axial CT showing a Stanford type B aortic dissection involving the descending aorta. White arrow: intimal flap. Black arrow: normal ascending aorta

Although magnetic resonance arteriography (MRA) is another option for visualizing the dissection, a contrast CT is still preferred because it is more readily available and can be performed quickly in the emergency setting (Figs. 9.3 and 9.4).

What Imaging Is Recommended if the Patient Is Hemodynamically Unstable and an Aortic Dissection Is Highly Suspected?

Hemodynamically unstable patients suspected of having a type A aortic dissection should be taken to the OR immediately, without chest CT scan, for surgical intervention.

Transesophageal echocardiography (TEE) can be performed in the operating room, while the patient is under general anesthesia and if confirmatory, surgery can begin immediately.

Management

What Is the First Step in Management of an Aortic Dissection?

Since high blood pressure will propagate the tear, it is critically important to maintain a blood pressure less than 120/80 mmHg and heart rate of 60 beats/min or less. This same management principle applies to all types of aortic dissection, regardless of location, and should be initiated as soon as the diagnosis is suspected. This is best done with intravenous beta-blockers. Beta-blockers decrease the shear forces on the aorta by decreasing the dp/dt (change in pressure/change in time).

Watch Out

Patients with significant aortic regurgitation or tamponade should not receive beta-blockers.

What Is the Next Step (After Starting Antihypertensives) Once the Diagnosis of Type A Dissection Is Established?

The patient should be taken urgently to the operating room for repair via median sternotomy. Depending on the exact location of the dissection, part of the ascending aorta may need to be replaced with a synthetic graft, a new aortic valve may need to be placed, and the coronary arteries may need to be reimplemented into the new graft.

What Is the Next Step (After Starting Antihypertensives) Once a Diagnosis of Type B Dissection Is Established?

The patient should be admitted to an ICU and the blood pressure closely monitored.

When Should Patients with Type B Dissection Undergo Surgical Repair?

Urgent surgical intervention is reserved for patients that develop complications (e.g., malperfusion syndrome) secondary to compromised perfusion to branches of the descending thoracic or abdominal aorta, or intractable pain despite blood pressure control. This would include evidence of limb ischemia or visceral (bowel, kidneys) ischemia. For chronic dissections, indications include aneurysmal dissection diameter of >5.0 to 6.0 cm or rapidly expanding aortic diameter (>1 cm per year).

What Are the Surgical Options for a Type B Dissection?

The preferred approach in most cases is thoracic endovascular aortic repair (TEVAR) with placement of a stent graft. Open repair via a thoracotomy is less commonly performed. Spinal cord ischemia is a complication specific to repair of dissections involving the thoracic aorta, as the blood supply to the spinal cord (via the artery of Adamkiewicz) may be interrupted. It is much less common with TEVAR than open repair.

What Are the Differences in Prognosis and Definitive Management Between Type A and Type B Aortic Dissections?

Table 9.4

	Type A dissection	Type B dissection
<i>Prognosis</i>	50% of patients die within 48 hours without surgical intervention, $<10\%$ will live beyond 1 month, MI and stroke portend an even worse prognosis	80% of patients survive with appropriate medical therapy
<i>Management</i>	Begin with medical therapy (e.g., β -blocker) and urgent surgical intervention	Begin with medical therapy only (in the absence of malperfusion syndrome): β -blocker (first line), nitroprusside, calcium channel blockers, morphine for analgesia (surgical repair is indicated if there is malperfusion)

Areas Where You Can Get in Trouble

Giving Beta-Blockers to a Patient with Aortic Dissection Complicated by Cardiac Tamponade or Severe Aortic Regurgitation

Beta-blockade in these patients will worsen hypotension and may precipitate cardiac arrest.

Confusing Type A Aortic Dissection with Acute MI

Patients with type A aortic dissection can present with coronary artery malperfusion and thus have a similar presentation as an acute MI. In patients with acute MI without aortic dissec-

tion, the MI is generally due to acute occlusion of a coronary artery due to rupture of an atherosclerotic coronary plaque. Treatment consists of antiplatelet agents, heparin, possibly fibrinolytic drugs, and emergent coronary catheterization to relieve the obstruction and possibly place a stent. If the diagnosis of a type A aortic dissection is missed, the patient may be incorrectly given heparin and taken to the coronary catheterization lab instead of the operating room for a sternotomy.

Area of Controversy

Endovascular Repair of a Stable Asymptomatic Type B Aortic Dissection

In patients with type B dissection, the descending aorta can progressively dilate with time, eventually requiring surgery if the diameter of the aneurysm exceeds 6 cm. Since endovascular repair of type B dissections is less invasive and is associated with fewer complications, some centers advocate early repair of the stable type B dissections in order to prevent a chronic enlargement of the aorta. However, most surgeons recommend only medical therapy for stable, asymptomatic type B dissections.

Summary of Essentials

History and Physical Exam

- Sudden onset of severe tearing chest pain radiating to upper back
- Risk factors: severe hypertension, atherosclerosis, advanced age, connective tissue disorders (Marfan's, Ehlers-Danlos), pregnancy, and cocaine abuse
- Look for evidence of acute aortic insufficiency, cardiac tamponade
- Look for evidence of malperfusion
- Stroke
 - Diminished pulses in an extremity or difference in blood pressure in each arm
 - Severe abdominal pain
 - Oliguria/anuria

Watch Out

- Aortic dissection can easily be missed
 - Acute MI can be caused by a type A dissection

Pathophysiology

- High shear stress and pulsatile blood flow can cause a tear that begins in the intima and splits the media, creating a true and a false lumen

- Expansion of the false lumen may occlude branch vessels and cause ischemia to the brain, viscera, or extremities

Classification

- Stanford A: involves ascending aorta/aortic arch
 - Can also involve descending aorta
- Stanford B: descending aorta (distal to left subclavian) only

Diagnosis

- Chest x-ray: widened mediastinum
 - Not present in 15–20%
- CT chest with IV contrast: if mediastinum is wide or suspicion for dissection is high
- Unstable patient: directly to OR with transesophageal echo

Management

- Immediate control of blood pressure: Beta-blocker preferred unless there is suspected tamponade or severe aortic regurgitation
- Type A dissection: immediate operative repair
 - Median sternotomy (replace ascending aorta with graft)
 - Possible aortic valve replacement
 - Possible reimplantation of coronary arteries
- Type B dissection: admit to ICU for blood pressure control
 - Surgery only if evidence of malperfusion or ongoing pain
- TEVAR preferred

Suggested Reading

- Braverman AC. Acute aortic dissection clinician update. *Circulation*. 2010;122:184–8.
- Hiratzka LF, Bakris GL, Beckman JA, et al. ACCF/AHA/AATS/ACR/ASA/SCA/SCAI/SIR/STS/SVM Guidelines for the diagnosis and management of patients with thoracic aortic disease. A report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines, American Association for Thoracic Surgery, American College of Radiology, American Stroke Association, Society of Cardiovascular Anesthesiologists, Society for Cardiovascular Angiography and Interventions, Society of Interventional Radiology, Society of Thoracic Surgeons, and Society for Vascular Medicine. *J Am Coll Cardiol*. 2010;55(14):e27–e129.



Hemoptysis, Cough, and Weight Loss

Ryan Ou and Peyman Benharash

Case Study

A 71-year-old male presents to his primary care physician with an 8-week history of cough with intermittent blood-tinged sputum. He denies fevers or sick contacts. However, he notes a 20-pound weight loss in the last 3 months and feeling more fatigued. He has a 40-pack-year smoking history. He previously worked as a welder in a shipyard for 30 years before retiring 5 years ago. His past medical history only includes hypertension. Breath sounds are equal without crackles. Cardiac exam also reveals a regular rate and rhythm. His blood pressure is 120/80 mmHg, and heart rate is 88/min. An initial chest x-ray reveals a mass in the right hilar region measuring 3.1 cm × 3.5 cm.

Diagnosis

What Is the Differential Diagnosis?

■ Table 10.1

Diagnosis	Comments
Primary lung cancer	Malignancy arising from lung epithelial or parenchymal cells
Metastatic disease	Pulmonary metastasis is the most common form of lung tumors, most commonly from colon, breast, prostate, and bladder primaries
COPD	Chronic inflammatory lung disease causing obstructed airflow from the lungs
ILD	Group of disorders that causes progressive scarring of lung tissue
CHF	CHF can cause increased congestion leading to back up into the pulmonary vasculature and parenchyma
Pneumonia	Infection and irritation of the lung parenchyma can present with cough and hemoptysis
Tuberculosis	Infection by <i>Mycobacterium tuberculosis</i> , often affects lungs, symptoms include fevers, hemoptysis, and weight loss
HIV	Respiratory manifestations of <i>HIV</i> include cough, dyspnea, pleuritic chest pain; cough can be productive of clear, purulent, or blood-streaked sputum
Other causes	Rheumatic (e.g., amyloidosis, sarcoidosis); infection (e.g., abscess, fungal infection, viral)

COPD chronic obstructive pulmonary disease, *ILD* interstitial lung disease, *CHF* congestive heart failure, *HIV* human immunodeficiency virus

What Is the Most Likely Diagnosis?

The chronicity of the patient's symptoms, the history of cigarette smoking, occupational exposure, and the finding of a pulmonary lesion on chest x-ray are highly suggestive of lung malignancy.

History and Physical

What Are the Risk Factors for Lung Cancer?

Smoking is the greatest risk factor for the development of a primary lung malignancy, and the risk is proportional to the magnitude of cigarette consumption. Environmental and occupational exposures also play an important role (see below). Other known factors include pulmonary fibrosis and HIV.

What Is the Importance of Occupational Exposure?

Historically, shipyard workers have been known to be frequently exposed to asbestos. Asbestos is a fibrous silicate mineral that is classically associated with development of mesothelioma. While up to 90% of mesothelioma is associated with asbestos exposure, only about 1% of patients with a history of asbestos exposure develop mesothelioma. Other exposures are listed in ■ Table 10.2. Welding is a known occupational risk factor.

■ Table 10.2 Occupational exposure

Occupational exposures	Source	Comments
Asbestos	Mining, construction, ship repair	Chronic inflammatory response leads to fibrosis, pleural disease, and mesothelioma
Silica	Mining, stone cutting, quarry	Chronic inflammation leading to PMF, COPD, and cancer
Beryllium	Alloy processing	Pneumonitis, chronic granulomatous disease, possibly lung cancer
Coal	Mining	PMF, COPD
Other metals (aluminum, chromium, nickel, cobalt, titanium, etc.)	Various sources	Ranges from pneumonitis to lung cancer

PMF pulmonary massive fibrosis, *COPD* chronic obstructive pulmonary disease

Pathophysiology

Does This Patient Have a Solitary Pulmonary Nodule?

No. A solitary pulmonary nodule (SPN) is a single lesion in the lung that is 3-cm or less and is surrounded by normal lung parenchyma (and therefore not abutting the hilum or pleura). It is typically discovered incidentally and is not associated with symptoms. A lesion that is >3-cm, as in this patient (who also has symptoms), is considered a pulmonary mass.

Watch Out

Pulmonary nodules must be at least 1-cm in size to be seen on chest x-ray, whereas CT scan can detect subcentimeter nodules.

How Is Lung Cancer Classified? Why Is It Important?

Lung cancer is divided into non-small cell lung cancer (80–85%) and small cell lung cancer (10–15%). Non-small cell lung cancer is further categorized into three major histologic subtypes: squamous cell carcinoma, adenocarcinoma, and large cell carcinoma (■ Table 10.3). Treatment is quite variable based on tumor type (discussed later).

■ Table 10.3 Lung cancer subtypes

Tumor type	Incidence	Comments
Adenocarcinoma	40%	Most common primary lung cancer; most likely to arise in non-smokers and often located peripherally
Squamous cell carcinoma	20%	Often hilar mass arising from the bronchus; can have cavitations; associated with smoking
Large cell carcinoma	20%	Often located peripherally; highly anaplastic; strong association with smoking
Small cell carcinoma	15%	Often centrally located; neoplasm of neuroendocrine Kulchitsky cells; undifferentiated and very aggressive
Other	5%	Carcinoid tumors, nests of neuroendocrine cells, can be central or peripheral; symptoms often due to mass effect

What Is the Epidemiology of Lung Cancer?

Lung cancer is the second most common primary malignancy in men and women; however it is the leading cause of death.

What Syndromes Are Often Associated with Lung Cancers?

■ Table 10.4

Tumor type	Common syndromes
Adenocarcinoma	Hypertrophic pulmonary osteoarthropathy, presents with clubbing and periostitis of small hand joints; Trousseau syndrome, characterized by recurrent, migratory thrombosis of superficial veins
Squamous cell carcinoma	Ectopic production of PTH-related protein, resulting in hypercalcemia and hypophosphatemia; Pancoast tumor (syndrome), due to location of the lesion (superior sulcus) this results in compression of the thoracic inlet with involvement of brachial plexus and cervical sympathetic nerves, causing severe pain in shoulder, atrophy of upper extremities, and Horner's syndrome (ptosis, miosis, anhidrosis)
Large cell carcinoma	Gynecomastia from secretion of <i>beta</i> -HCG; SVC syndrome; presents with increased dyspnea, increased jugular venous pressure, and facial swelling
Small cell carcinoma	Ectopic production of ACTH or ADH; Lambert-Eaton syndrome, autoimmune disorder of postsynaptic Ach receptors in muscle fibers
Carcinoid	Carcinoid syndrome (flushing, diarrhea, wheezing, and salivation)

PTH parathyroid hormone, *HCG* human chorionic gonadotropin, *SVC* superior vena cava, *ACTH* adrenocorticotropic hormone, *ADH* antidiuretic hormone

Watch Out

Trousseau's syndrome (superficial migratory thrombophlebitis) is also associated with pancreatic cancer. Trousseau's sign (carpopedal spasm with blood pressure cuff inflated) is a sign of hypocalcemia.

What Are Common Sites of Metastasis for Primary Lung Cancer?

Common sites include the brain, bone, adrenals, liver, and kidney. Hypercalcemia in a patient with suspected lung cancer suggests bony metastasis (or rarely ectopic PTH-related production).

Watch Out

Hoarseness in a patient with a suspected chest tumor (e.g., lung cancer) suggests recurrent laryngeal nerve involvement.

Workup**How Does One Determine the Likelihood of Malignancy When a Pulmonary Lesion Is Detected on Chest X-Ray?**

There are several scoring systems available, including one from the Mayo Clinic. Malignancy risk increases with such variables as a history of smoking, size of the lesion, presence of spiculation, location of the lesion (upper lobe more worrisome), and history of extrapulmonary cancer.

What Are the Initial Diagnostic Steps for Suspected Lung Cancer?

After initial history and physical, a chest x-ray should be the first step. A pulmonary lesion may be new or old. Making a comparison to prior films is particularly useful. If there are no prior films, the lung lesion was not present earlier, or if it was small and has grown, a chest CT should follow.

What Is the Role of PET Scan?

Although a suspected whole-body PET scan may provide useful information, it is not routinely ordered. Since PET scan relies on increased glucose metabolism, false positives can occur with inflammatory masses (as they are metabolically active), and false negatives can be seen with small nodules and with malignancies that have a low metabolic rate (e.g., carcinoid).

Should a Biopsy Be Performed?

Suspicious lung masses should be biopsied. Depending on the location and size, the biopsy can be done with a needle under CT guidance (for peripheral lesions) or with bronchoscopy (for central or endobronchial lesions).

Management**How Does the Lung Cancer Type Influence Management?**

Small cell lung cancer is a disseminated disease in most patients at time of presentation. Initial treatment primarily involves a combination of chemotherapy and radiation therapy. For more

disseminated disease, chemotherapy is used as initial therapy followed by prophylactic cranial irradiation and thoracic radiation therapy. For other lung cancers, surgical resection is the treatment of choice, provided it is potentially curable. Unfortunately, by the time the patient presents with symptoms of lung cancer, many are already beyond curative resection.

What Is the Importance of Preoperative Evaluation?

A preoperative evaluation with forced expiratory volume in 1 s (FEV1) and diffusing capacity for carbon monoxide (DLCO) is recommended in all patients in whom a lung resection is considered. A FEV1 and DLCO >80% predicted is generally considered low risk.

Areas of Controversy**Is Universal Screening for Lung Cancer Appropriate?**

The implementation of universal screening for lung cancer has potential benefits such as early detection to increase overall survival rate; however studies have shown that screening had high false positive that often led to invasive studies that lead to morbidity and potential mortality. Several randomized clinical trials have examined the efficacy of screening, but no consensus has been reached. Many expert groups in the USA have adopted the findings from these trials but with slight differences in their recommendations. Another concern is that use of routine imaging introduces further radiation that may independently raise the risk of developing cancers. In summary, prevention is more effective than universal screening for lung cancer.

Is Screening of Benefit to Any Group?

The US Preventive Services Task Force (USPSTF) recommends annual screening for lung cancer using low dose CT in adults aged 55 to 80 with a 30-pack-year smoking history that are currently still smoking or recently quit within the last 15 years. However, the National Comprehensive Cancer Network (NCCN) stratifies patients based on risk factors such as age, smoking history, and secondary exposures and only recommends low dose CT for high-risk patients.

Summary of Essentials**History and Physical Exam**

- Chronic cough with hemoptysis and unintentional weight loss.

- Risk factors: significant history of smoking, occupational exposure, advanced age, pulmonary fibrosis, HIV.
- Physical exam may reveal no pertinent findings.
- High suspicion from history of symptoms and exposure.

Watch Out

- A primary lung malignancy can be easily missed given possible absence of physical symptoms.

Pathophysiology

- Malignancy arising from the airways or pulmonary parenchyma.
- Second most common primary malignancy and leading cause of death in men and women.
- Risk of disease proportional to magnitude of cigarette consumption.
- Occupational exposure can also increase risk (classically asbestos).
- Associated with a range of paraneoplastic syndromes.

Classification

- Divided into NSCLC (adenocarcinoma, squamous cell carcinoma, large cell carcinoma), SCLC, and other (carcinoid tumor)

Diagnosis

- Initial chest x-ray with comparison to prior films, if possible
- Chest CT with contrast and tissue sampling for staging
- Biopsy (CT guided or bronchoscopy)

Management

- Treatment based on NSCLC vs SCLC
- NSCLC
 - Localized disease (stage I/II) – complete surgical resection if possible followed by adjuvant chemotherapy. Radiation therapy can be used in nonsurgical candidates.
 - Mediastinal involvement (stage III) – combined modality involving chemoradiotherapy and surgery in select patients.
 - Disseminated (stage IV) disease – multisystem approach or symptom-based palliative therapy.
- SCLC
 - Limited stage – combination of chemotherapy and radiation therapy
 - Extensive stage – initial chemotherapy, followed by radiation therapy, prophylactic cranial and thoracic irradiation
- Screening
 - Age and frequency controversial, requires individualized approach depending on risk stratification
 - Low dose CT for patients age 55 to 80 with 30-pack-year smoking history currently still smoking or cessation within last 15 years

Suggested Reading

- Aberle DR, Adams AM, Berg CD, et al. Reduced lung-cancer mortality with low-dose computed tomographic screening. *N Engl J Med.* 2011;365(5):395–409.
- Dela Cruz CS, Tanoue LT, Matthey RA. Lung cancer: epidemiology, etiology, and prevention. *Clin Chest Med.* 2011;32(4) <https://doi.org/10.1016/j.ccm.2011.09.001>.
- Herbst RS, Heymach JV, Lippman SM. Lung cancer. *N Engl J Med.* 2008;359(13):1367–80.
- Jemal A, Ward E, Hao Y, Thun M. Trends in the leading causes of death in the United States, 1970–2002. *JAMA.* 2005;294(10):1255–9.

Question Set:

Cardiothoracic

Questions

1. A 63-year-old woman with diabetes is recovering in the ICU after receiving a coronary artery bypass graft (CABG). On the sixth postoperative day, she starts complaining of chest pain. Her temperature is 38.7 °C, blood pressure is 108/72 mmHg, and pulse is 125/min. On physical exam, there is drainage from her sternal wound, and there is a crunching sound heard with a stethoscope over the precordium during systole. The sternum feels somewhat unstable to palpation. Her laboratory examination is significant for an elevated white blood count ($16.7 \times 10^3/\mu\text{L}$). Chest x-ray is pending. What is the most likely diagnosis?

 - (A) Acute pericarditis
 - (B) Postoperative myocardial infarction (MI)
 - (C) Empyema
 - (D) Acute mediastinitis
 - (E) Pneumonia
2. A 75-year-old male with severe aortic stenosis has a routine checkup at his primary care doctor. Which of the following symptoms portends the worst prognosis?

 - (A) Exertional chest pain
 - (B) Swollen legs
 - (C) Fainting spells
 - (D) Mid-systolic murmur heard loudest at the upper right sternal border
 - (E) Small head nodding movements at each heartbeat
3. Which of the following is the most important risk factor for aortic dissection?

 - (A) History of coronary artery bypass grafting (CABG)
 - (B) Giant cell arteritis
 - (C) Pregnancy
 - (D) Hypertension
 - (E) Bicuspid aortic valve
4. A patient is diagnosed with type A aortic dissection, and there is concern for cardiac tamponade. Which of the following findings would be the *most* consistent with cardiac tamponade?

 - (A) Pulsus bisferiens
 - (B) Watson's water hammer pulse
 - (C) Peaked T-waves
 - (D) Equalization of central pressures
 - (E) Pulsus alternans
5. A 67-year-old male is diagnosed with a type B aortic dissection. At the time of initial presentation on the previous day, his blood pressure was 178/110 mmHg. He was treated with intravenous beta-blocker, and his blood pressure was reduced to 112/60 mmHg and has remained in that range. However, one day later, he suddenly

develops severe abdominal pain. His blood pressure is measured to be 110/56 mmHg. Which of the following is the most likely explanation?

- (A) *C. difficile* infection
- (B) Occlusion of the superior mesenteric artery
- (C) Pancreatitis
- (D) Aortoenteric fistula
- (E) Diverticulitis

6. An obese 52-year-old man with a 50-pack-year smoking history and hypertension controlled with chlorthalidone presents to a remote hospital without interventional capabilities with 30 min of crushing chest pain radiating to his left arm and jaw. Troponin and CK-MB levels are elevated, and electrocardiogram shows ST-segment elevations in leads V1 through V4. He is treated with thrombolytic therapy, and his symptoms resolve. The next morning, the patient is found dead in his bed. Which of the following is the most likely cause of death?
- (A) Ventricular free wall rupture
 - (B) Embolic stroke
 - (C) Ventricular arrhythmia
 - (D) Post-MI pericarditis
 - (E) Overwhelming infection

7. A 65-year-old female has breast cancer and a remote history of congestive heart failure. Her physician is planning to administer a chemotherapeutic agent that has potential for cardiac toxicity. Which of the following is the most accurate test to measure ejection fraction?
- (A) Multigated acquisition (MUGA) scan
 - (B) Echocardiography
 - (C) Electrocardiogram
 - (D) Coronary angiography
 - (E) Exercise stress test

8. A 76-year-old man is driven to the emergency department by his wife and is complaining of severe chest pain that started 30 minutes prior. He denies abdominal or extremity pain. Pulses in the arms and legs are 2+. His kidney function is normal. CT scan shows an aortic dissection. Which of the following findings on CT scan would most strongly indicate the need for urgent surgery?
- (A) Dissection of the entire descending thoracic aorta
 - (B) Involvement of common iliac arteries
 - (C) Involvement of renal arteries
 - (D) Extension into mesenteric vessels
 - (E) Involvement of origin of innominate artery

9. A 65-year-old female is diagnosed with aortic dissection beginning 2 cm distal to the left subclavian artery and extending distally. Her blood pressure is 180/70 mmHg, and her heart rate is 88/min. Peripheral pulses are all 2+, and her abdomen is soft and nontender. What is the next best step in treatment?
- (A) Surgical repair
 - (B) Aggressive IV fluids
 - (C) Labetalol drip
 - (D) Endovascular repair
 - (E) Nicardipine drip

10. A 65-year-old man is rushed to the emergency department by ambulance after he suddenly lost strength and sensation in his left leg and arm. He was hospitalized 2 months ago with a non-ST elevated myocardial infarction (NSTEMI). He is compliant



with all of his medications and had been recovering well until the present episode. Electrocardiogram shows normal sinus rhythm without evidence of ischemia. Chest x-ray is unremarkable. Carotid ultrasound demonstrates <30% stenosis bilaterally. What is the most likely etiology of the patient's present symptoms?

- (A) Ventricular thromboembolism
- (B) Septic embolism to the brain
- (C) Type A dissection involving the right carotid artery
- (D) Thromboembolism from the left atrial appendage
- (E) Paradoxical venous thromboembolism

11. A 66-year-old man is recovering in the ICU after receiving a coronary artery bypass graft (CABG). On the fourth postoperative day, he complains of chest pain. He is sweating, anxious, short of breath, and nauseated. Electrocardiogram shows evidence of right-sided myocardial infarction (MI). His blood pressure is 98/65 mmHg. What is the next best step in management?
- (A) Administer 1 liter of normal saline
 - (B) Nitroglycerin
 - (C) Nitroprusside
 - (D) Nifedipine
 - (E) Lisinopril
12. A 65-year-old male presents with a painful nodule in his wrist that is determined to be a ganglion cyst. Despite attempts at aspiration, it recurs. He is unable to work as a computer programmer, is on disability, and is feeling depressed. He is scheduled for wrist surgery. He reports having been discharged 1 week ago for an episode of chest pain. Troponins were elevated at that time, but there was no elevation of his ST segment. Which of the following is the best recommendation?
- (A) Proceed with surgery with intraoperative transesophageal echocardiography
 - (B) Proceed with surgery but perform under local anesthesia with sedation
 - (C) Proceed with surgery only if echocardiogram shows normal ejection fraction
 - (D) Proceed with surgery after aggressive beta blockade to get heart rate into low 60s
 - (E) Postpone surgery for at least 4 weeks
13. A 65-year-old male is about to undergo an elective inguinal hernia repair. Which of the following findings on history or physical would portend the highest operative risk?
- (A) Systolic, crescendo-decrescendo murmur at the sternal border of the right second intercostal space radiating into the neck
 - (B) A history of myocardial infarction 10 years ago
 - (C) Insulin-dependent diabetes mellitus with an elevated Hgb-A1C
 - (D) Renal insufficiency not yet on dialysis
 - (E) Smoking
14. A 65-year-old male undergoes a videoscopic right upper lobectomy for squamous cell lung cancer. On postoperative day 1, he suddenly develops chest pain and diaphoresis. Blood pressure is 120/60 mmHg, and heart rate is 80/min. Serial highly sensitive troponin-I assays demonstrate levels of 0.4, 0.3, and 0.01 ng/dL. Electrocardiogram demonstrates nonspecific T-wave changes with no ST-segment elevation. Following the administration of oxygen, morphine, aspirin, and a beta-blocker, his symptoms resolve. What is the next step in the management?
- (A) Intravenous thrombolytic therapy
 - (B) Percutaneous coronary intervention (PCI) with stenting
 - (C) PCI without stenting
 - (D) Coronary artery bypass graft (CABG)
 - (E) Continue medical management and reevaluate as outpatient in 4–6 weeks

15. A 17-year-old black male presents for a pre-participation physical before track season. A harsh systolic murmur is heard at the second right intercostal space. He denies ever experiencing chest pain, dizziness, or difficulty breathing. Which of the following would be expected on further workup?
- (A) T-wave inversion on electrocardiogram
 - (B) Laterally displaced point of maximum impulse (PMI) on palpation
 - (C) Weak femoral pulses compared to brachial pulses
 - (D) Increased intensity of the murmur with Valsalva maneuver
 - (E) Increased intensity of the murmur with squatting
16. A 65-year-old woman arrives to the emergency department complaining of chest pain. Her past medical history includes hypertension, atherosclerosis, and coronary artery disease. She underwent a coronary artery bypass graft (CABG) 3 weeks ago for three-vessel disease. She reports that her chest pain worsens with inspiration and lessens when leaning forward. A friction rub is heard on auscultation. Electrocardiogram shows global ST elevation. What is the most likely diagnosis?
- (A) Myocarditis
 - (B) Myocardial infarction
 - (C) Cardiac tamponade
 - (D) Acute pericarditis
 - (E) Pulmonary embolism
17. A 40-year-old male presents with acute chest pain and nausea. Serum troponin levels are elevated, and the electrocardiogram demonstrates ST-segment elevation. Which of the following would be the strongest contraindication to intravenous thrombolytic therapy?
- (A) Right knee arthroscopic surgery 1 month ago
 - (B) Recently completed antibiotic course for *H. pylori* infection
 - (C) Wide mediastinum on chest x-ray
 - (D) History of alcohol abuse
 - (E) Endovascular aortic aneurysm repair 1 month ago

Answers

1. Answer D
- This patient's presentation is most concerning for acute mediastinitis. This is a life-threatening infection of the mediastinum with a very high mortality rate that is most commonly associated with cardiac surgery. The incidence rate is 1–2% following CABG. The source of infection may be a sternal wound infection, combined with instability of the sternum that permits bacteria to enter the mediastinum. *Hamman's sign* is a crunching sound heard with a stethoscope over the precordium during systole and is suggestive of acute mediastinitis. Patients will frequently present with chest pain, increased drainage from the sternal wound, fevers, and leukocytosis. Chest radiograph findings include a widened mediastinum with or without pneumomediastinum or air-fluid levels within the mediastinum. A CT scan can also support the diagnosis by demonstrating dehiscence of the sternum and stranding, fluid and air pockets within the anterior mediastinum. Management includes surgical debridement, drainage, antibiotics, and rewiring the sternum. Acute pericarditis will present with pleuritic chest pain that lessens when leaning forward, friction rub heard on auscultation, and characteristic electrocardiogram findings (global ST elevation) (A). Pneumonia would present with shortness of breath, productive cough, and abnormal lung sounds (E). Postoperative MI would not be expected to present with evidence of systemic inflammation (B). Empyema is defined as pus in the pleural space and would not explain the physical exam findings of sternal instability and Hamman's sign (C). CT scan would demonstrate a loculated fluid collection within the right or left pleural cavity.



- ✓ 2. Answer B

The classic signs of severe aortic stenosis are angina, syncope, and congestive heart failure (which may manifest as swollen legs) (A, C). Of the three, congestive heart failure portends the worst prognosis, with median survival as low as 2 years. A loud mid-systolic murmur indicates hemodynamically significant obstruction but is a better prognostic sign than an absent murmur, which indicates low blood flow across the valve (D). Small head nodding movements with each heartbeat are known as de Musset's sign and is found in aortic regurgitation (E).
- ✓ 3. Answer D

All of the above are risk factors for aortic dissection. However, the most significant risk factor for aortic dissection is systemic hypertension (A–C, E).
- ✓ 4. Answer D

In cardiac tamponade, fluid (blood or effusion) in the pericardial space externally compresses the heart, which limits diastolic filling and reduces stroke volume. Since pericardial fluid is free flowing, the pressure is distributed equally along the pericardium. As this continues the rising pressure in the pericardium is transmitted to all four cardiac chambers resulting in equalization of central pressures. Pulsus bisferiens, also known as a biphasic pulse, refers to two strong systolic pulses with a mid-systolic dip, in other words, two pulses during systole (A). It can be seen in aortic regurgitation with or without aortic stenosis and hypertrophic cardiomyopathy. Watson's water hammer pulse is a pulse with a rapid upstroke and descent seen in patients with aortic regurgitation (B). Peaked T-waves are most often associated with hyperkalemia (C). It is unlikely to be seen in patients with cardiac tamponade since their electrocardiogram findings are characteristically low voltage. Pulsus alternans is a physical exam finding wherein the amplitude of a peripheral pulse changes from beat to beat associated with changing systolic blood pressure (E). It is most commonly caused by left ventricular failure.
- ✓ 5. Answer B

Sudden onset of severe abdominal pain in association with an aortic dissection should always raise suspicion for malperfusion of the bowel which can lead to bowel ischemia, gangrene, and death. This most likely would occur if the dissection extends into, and suddenly occludes, the superior mesenteric artery, which supplies blood to the bowel from the ligament of Treitz to the mid-transverse colon. It is also important to recognize that bowel ischemia early on causes excruciating pain in the absence of peritonitis ("pain out of proportion to physical exam"). He has not been on broad-spectrum antibiotics and has no reason to have *C. difficile* infection, which most often presents with vague abdominal pain and diarrhea (A). Pancreatitis presents with epigastric pain radiating to the back, nausea, vomiting, anorexia, fever, and tachycardia and is most commonly associated with cholelithiasis and alcohol abuse (C). Aortoenteric fistula is a possible long-term sequela in patients who have had an intra-aortic synthetic graft placed (D). Diverticulitis is a common cause of left lower quadrant abdominal pain in elderly patients and does not typically cause such sudden severe pain (E).
- ✓ 6. Answer C

This patient is presenting with ST-elevation myocardial infarction (MI). It is important to know the timing of causes of death after MI. In the first 48 h after MI, death is likely due to ventricular arrhythmia. If arrhythmia occurs after 48 h, an implantable defibrillator should be placed. Ruptures of the myocardium, either as a ventricular septal rupture or free wall rupture, usually do not occur until 4–5 days after MI, at which point the dead myocardium has been weakened by the body's inflammatory response (A). Post-MI pericarditis, also known as *Dressler's syndrome*, usually occurs weeks or months after MI or cardiac surgery (D). An embolic stroke would present with sudden onset

of numbness on one side of the body, cranial nerve deficits, and/or aphasia (B). It is unlikely to cause death so quickly. There is no reason to believe the patient has sustained an overwhelming infection (E).

✓ 7. Answer A

The MUGA scan is the most accurate test in measuring ejection fraction. It is a non-invasive nuclear test that uses a radioactive isotope (technetium) to evaluate the function of the ventricles. Though not as accurate, an echocardiogram is used more commonly because it is cheaper and more readily available and can look for valve function as well as focal areas of wall motion abnormality (B). Electrocardiogram and exercise stress test are unable to measure a patient's ejection fraction (C). Coronary angiography is considered the gold standard in identifying coronary artery disease and can estimate ejection fraction but is not as accurate (D). In an exercise stress test, the patient typically walks on a treadmill while monitored with an electrocardiogram to look for changes suggestive of coronary ischemia (E).

✓ 8. Answer E

It is important to rapidly identify Stanford type A dissections, as they require urgent surgical intervention due to the fact that they can lead to cardiac tamponade, acute aortic valve insufficiency, acute myocardial infarction, and stroke. A Stanford type A dissection involves the ascending aorta and/or the aortic arch. Thus, an aortic dissection involving the innominate artery is a Stanford type A (A–D). Stanford type B aortic dissection is more common. It begins in the descending aorta, distal to the takeoff of the left subclavian artery. Stanford type B dissections are much less likely to cause acute complications since the ascending aorta/aortic arch is not involved. A type B dissection may involve the mesenteric, renal, or iliac arteries, but not occlude them, as blood may continue to flow normally (either through the true or the false lumen). Most can be managed medically with blood pressure control (beta-blockers). Surgical intervention is needed if the involvement of these vessels leads to malperfusion (such as leg ischemia, bowel ischemia, or renal failure).

✓ 9. Answer C

Based on the description of the site of the dissection, this is a type B aortic dissection. These are usually managed medically unless the patient has evidence of malperfusion (A). Since her peripheral pulses are all 2+ and her abdomen is soft and non-tender, there is no evidence of malperfusion. The goal is to maintain a relatively low blood pressure in order to minimize stress on the aorta. Aggressive IV fluids will not reduce blood pressure and may actually raise it (B). Nicardipine will lower blood pressure, but intravenous beta-blocker is the treatment of choice because it also reduces the rate of pressure increase with each beat of the heart, which lowers the stress on the aortic wall (E). Endovascular therapy is not routinely needed for most type B dissections (D).

✓ 10. Answer A

Patients with a recent history of myocardial infarction are at risk of thrombus formation on the scarred endocardium, which can then embolize to the brain and cause a stroke. Patients with a recent history of MI and evidence of thrombus on echocardiography should be treated with warfarin to maintain an INR of 2–3 and followed up within 3 months. Thromboembolism from the left atrial appendage is a concern in patients with atrial fibrillation (D). Paradoxical venous thromboembolism is a concern in patients with an atrial septal defect or patent foramen ovale, wherein a deep venous thrombus can travel through the defect into the left heart and ultimately to the brain (E). Septic embolism is a concern in IV drug abusers and can lead to cerebral abscess (B). Type A dissection would usually present with severe chest pain radiating to the back (C).



✓ 11. Answer A

This patient has a postoperative right-sided MI, resulting in compromised cardiac output secondary to decreased preload. One of the steps in management of *right-sided* MI is to administer fluids to help increase filling of the heart. Avoid nitrates in these patients as it may further reduce preload (B–C). Acutely, patients with MI need oxygen, aspirin, analgesics, and beta-blockers. Oxygen should be used selectively as it is considered a systemic vasoconstrictor and can further reduce coronary blood flow. Dihydropyridine calcium channel blockers, such as nifedipine, are contraindicated in MI because of the associated peripheral vasodilation that may lead to reactive tachycardia and subsequently result in even more stress on the heart (D). ACE inhibitors (e.g., lisinopril) should be considered for long-term treatment after the acute episode has resolved (E).

✓ 12. Answer E

This patient has a NSTEMI. Proceeding with elective surgery 1 week after an acute MI is inappropriate (A–D). Patients with a recent MI are at significantly increased cardiac risk during non-cardiac surgery, particularly within the first month after MI. Although performing the operation under local anesthesia with sedation seems appealing, there is still considerable stress and cardiac risk with such an approach (B). The best recommendation for this patient is to postpone surgery for at least 4 weeks. At that point, consideration should still be given to cardiac stress testing prior to surgery or even further surgical delay, as the cardiac risk persists for at least 6 months after an MI.

✓ 13. Answer A

Major predictors of adverse postoperative cardiac events must be identified prior to elective non-cardiac surgery. These include recent (within 1 month) myocardial infarction, unstable or severe angina, decompensated congestive heart failure, and significant arrhythmias. Such cardiac conditions require postponing surgery and performing further cardiac workup. A systolic, crescendo-decrescendo murmur at the sternal border of the right second intercostal space radiating into the neck is highly suggestive of aortic stenosis and would require an echocardiogram to rule out severe aortic stenosis. Aortic stenosis impairs coronary perfusion, which can become further exacerbated during induction of anesthesia. From all the choices listed, it portends the highest operative risk. Lee's revised cardiac risk index identifies intermediate risk factors; these include known coronary artery disease, history of CHF, history of stroke or transient ischemic attack, insulin-dependent diabetes, creatinine >2.0 mg/dL, and high-risk surgery (i.e., aortic) (B–D). Adding a point for each factor and assigning a score (from 0 to 6) are highly effective in stratifying cardiac risk. Interestingly, smoking has not been shown to be an independent risk factor for adverse perioperative cardiac events in most studies (E).

✓ 14. Answer E

The patient has suffered a postoperative NSTEMI. Most NSTEMI (as opposed to a STEMI) in the postoperative setting are managed without PCI with a combination of oxygen, morphine for pain relief, aspirin, and a beta-blocker. Optimally, an additional antiplatelet agent (such as clopidogrel) and intravenous heparin are also given, but this depends on how recent the operation was and the potential for postoperative bleeding. Consideration should be given to stress testing at 4–6 weeks after surgery, and depending on the results, PCI is then considered. Urgent PCI is indicated in the setting of a STEMI, and in certain high-risk NSTEMIs (continued rise in troponins, ongoing chest pain), but will require clopidogrel (again may not be desirable so soon after surgery) if a stent is placed (B–C). The patient described has a down trend of troponins and relief of symptoms, further supporting medical management. Emergent CABG would be considered if PCI fails or is not technically feasible with severe three-vessel disease (D). Emergent operations for acute MI continue to have a high mortality despite many technological advances in myocardial protection. Thrombolytic therapy is an alternative when PCI is not available but would be contraindicated within 2–3 weeks of major surgery (A).

✓ 15. Answer D

The patient likely has hypertrophic obstructive cardiomyopathy, an asymmetric thickening of the ventricular septum that creates a narrowing of the left ventricular outflow tract. Vigorous exercise places him at increased risk of sudden cardiac death. T-wave inversion would be found in ischemic heart disease and would be very unlikely in an otherwise healthy 17-year-old (A). Laterally displaced PMI would be found in patients with congestive heart failure, also very unlikely in this patient (B). Weak femoral pulses compared to brachial pulses are a finding in coarctation of the aorta and would not create a harsh systolic murmur (C). Murmurs due to aortic regurgitation, mitral regurgitation, and ventricular septal defect increase in intensity with squatting (E).

✓ 16. Answer D

Acute pericarditis is inflammation in the pericardial sac accompanied by pericardial effusion. It can occur following post-MI (termed Dressler's syndrome), chest radiation, or recent heart surgery. Patients present with pleuritic chest pain that lessens when leaning forward, friction rub heard on auscultation, global ST elevation, and PR depression. Patients with myocarditis (A) usually present with signs and symptoms of acute decompensating heart failure (e.g., tachycardia, gallop, mitral regurgitation, and edema) (A). Chest pain accompanied with MI would not be expected to lessen with leaning forward (B). Furthermore, *global* ST elevation would not be expected. Cardiac tamponade can occur once the effusion reaches a critical mass in which cardiac output is compromised (C). Pulmonary embolism can present with pleuritic chest pain, but it will not be influenced by positioning and is more likely to have electrocardiogram findings suggestive of right heart failure (E).

✓ 17. Answer C

Wide mediastinum on chest x-ray is concerning for aortic dissection. Patients with type A aortic dissection can present with coronary artery malperfusion and thus have a similar presentation as an acute myocardial infarction. Suspected aortic dissection is considered an absolute contraindication to thrombolysis in patients with myocardial infarction. The remaining choices are all relative contraindications for intravenous thrombolytics (A–B, D–E).

Endocrine

Michael W. Yeh

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Incidentally Discovered Adrenal Mass on CT Scan

Eugene J. Park, Masha J. Livhits, and Michael W. Yeh

Case Study

A 55-year-old female was involved in a motor vehicle accident, at which time she underwent an abdominal CT scan that was negative for any injury. However, a 1.7-cm right adrenal nodule was incidentally noted. The patient complains of difficulty losing weight but denies any recent weight gain, abnormal hair growth, or muscle

weakness. She has a long-standing history of diabetes and hypertension. She denies headache, palpitations, and flushing. Physical exam is significant for central obesity, but she does not have supraclavicular fat accumulation or purple striae. Workup for the adrenal mass revealed an elevated 24-hour urine cortisol level

(170 mcg/dL; normal <45 mcg/dL). This was followed by a low-dose dexamethasone suppression test, which resulted in lack of cortisol suppression (AM cortisol 14.2 mcg/dL, normal <2 mcg/dL). Further biochemical workup including catecholamines and metanephrines as well as plasma aldosterone and renin levels was normal.

Diagnosis

What Is Meant by the Term Adrenal Incidentaloma?

An adrenal incidentaloma is an incidentally discovered mass seen on imaging performed for an unrelated reason (■ Fig. 11.1). Approximately 5% of patients who undergo an abdominal CT scan will have an incidentally discovered adrenal mass.

typically secrete one of three hormone types: cortisol, aldosterone, or catecholamines (epinephrine and norepinephrine). Malignant cancers, typically adrenocortical carcinoma, are defined by the presence of local invasion into adjacent organs, blood vessels or lymph nodes, or distant metastasis. Adrenocortical carcinomas may also be associated with hormonal hypersecretion. Finally, the adrenal glands are a frequent site for metastasis from other primary tumors, most commonly the lung and breast. The following chart provides an overview of common adrenal incidentalomas:

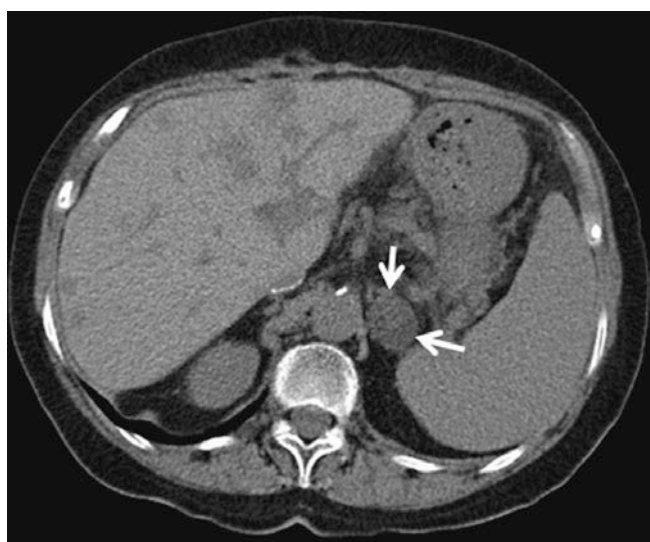
■ Table 11.1

Diagnosis	Prevalence	Clinical presentation
<i>Hypercortisolism (Cushing's syndrome)</i>	7%	Weight gain, central obesity, muscle weakness, poor wound healing, hirsutism, amenorrhea, depression, hypertension, diabetes mellitus
<i>Hyperaldosteronism (Conn's syndrome)</i>	1%	Muscle cramps, weakness, hypertension
<i>Catecholamine hypersecretion (pheochromocytoma)</i>	5%	Episodic tachycardia, sustained or episodic hypertension, headache, flushing, palpitations
<i>Androgen hypersecretion</i>	<1%	Virilization, hirsutism, menstrual abnormalities
<i>Benign, nonfunctional mass (myelolipoma, adenoma, cyst, hematoma, granuloma/infection)</i>	80%	Often asymptomatic; may have specific history related to trauma or infection (e.g., tuberculosis)
<i>Adrenocortical carcinoma</i>	5%	Abdominal pain (mass effect); symptoms related to functional tumor, large >6 cm
<i>Metastasis</i>	2% ^a	History of extra-adrenal tumor (most commonly lung or breast tumor; also melanoma, lymphoma, and kidney and ovary tumors)

^aIf patient has history of extra-adrenal tumor, prevalence of metastasis is up to 70%

What Is the Differential Diagnosis for an Incidentally Discovered Adrenal Nodule?

The differential for an adrenal mass is broad, given the variety of cell types present in the adrenal gland. The two key defining characteristics are whether the nodule is functional (associated with hormone hypersecretion) and whether it is malignant (has potential to recur and metastasize). Nonfunctional benign lesions include nonfunctional adenomas, myelolipomas, and cysts. These make up the majority of incidentally discovered asymptomatic adrenal nodules. Functional tumors



■ Fig. 11.1 Axial CT showing a small incidentaloma – an asymptomatic adrenal nodule discovered incidentally

What Is the Most Likely Diagnosis?

Given the small size of the mass and the evidence of cortisol hypersecretion, it is most likely a benign cortisol-secreting adrenal adenoma.

History and Physical

What Are the Findings on History and Physical Examination in a Patient that Hypersecretes Cortisol?

Physical exam findings include truncal obesity and fat accumulation around the head (moon facies) and neck (buffalo hump). Proximal muscle wasting can make it difficult for patients to stand from a seated position or climb stairs. The skin thins out, resulting in purple striae on the abdomen and extremities, easy bruising, and a reddish coloration of the face (plethora). Women may present with amenorrhea and hirsutism. Patients often have associated metabolic conditions (i.e., obesity, diabetes, elevated cholesterol or lipid levels, and hypertension). Hypercortisolism is also associated with osteoporosis, poor wound healing, and psychiatric symptoms.

What Is the Difference Between Cushing's Syndrome and Cushing's Disease?

Most hypercortisolism is iatrogenic or exogenous. Pharmacologic glucocorticoids are administered for a spectrum of inflammatory conditions and for immunosuppression following organ transplantation. *Cushing's syndrome* describes the cluster of clinical findings (signs and symptoms) associated with glucocorticoid excess (described above), regardless of the underlying cause. In other words, patients with Cushing's syndrome may be receiving exogenous glucocorticoids, have a cortisol-producing adrenal tumor, or have a tumor producing adrenocorticotrophic hormone (ACTH). The latter two represent endogenous causes of hypercortisolism. The majority of endogenous cases arise from ACTH hypersecretion, which is almost always caused by a pituitary tumor. *Cushing's disease* is an endogenous form of hypercortisolism due to an ACTH-producing pituitary adenoma. A second, much rarer cause of ACTH-dependent Cushing's syndrome is an ectopic source of ACTH production (e.g., non-small cell lung cancer and bronchial carcinoids). ACTH-independent hypercortisolism occurs in up to 15% of patients with endogenous hypercortisolism, most commonly from a single adrenal adenoma (80% of ACTH-independent cases). A minority of patients have bilateral adrenal hyperplasia or multiple adrenal nodules.

What Is the Clinical Presentation of an Adrenal Nodule that Hypersecretes Aldosterone?

The classical hallmark of hyperaldosteronism is hypertension with hypokalemia; however, hypokalemia is only seen in 50% of reported cases today. Hyperaldosteronism should be considered in patients with refractory hypertension requiring three or more antihypertensive agents. Hypokalemia, if present, may present with muscle cramping, muscle weakness, or rarely paralysis. Patients with hyperaldosteronism often show an excellent response to spironolactone, an aldosterone antagonist.

What Is the Clinical Presentation of a Pheochromocytoma?

Patients with pheochromocytoma most often present with sustained or episodic hypertension. Though only a minority present with the classic triad of headache, flushing, and palpitations, more than 90% complain of at least one of these symptoms.

What Signs and Symptoms Should Raise Suspicion for an Adrenocortical Carcinoma?

Adrenocortical carcinomas are highly lethal malignancies (5-year survival <25%) which often present at an advanced stage after having grown in a quiescent fashion. Approximately 60% are functional. The most common hormone hypersecretion associated with adrenocortical carcinoma is *Cushing's syndrome*, with virilization being a distant second and feminization a very distant third. Patients with nonfunctional tumors may present with an abdominal mass, abdominal pain, nausea, anorexia, early satiety, or weight loss. Approximately 75% of adrenocortical carcinomas are >6 cm at the time of presentation (■ Figs. 11.2 and 11.3).



■ Fig. 11.2 Axial CT of the normal left adrenal gland



Fig. 11.3 Axial CT showing a large adrenal mass consistent with malignant adrenal cortical carcinoma

Pathophysiology

What Is the Most Common Adrenal Mass?

The most common adrenal mass is a nonfunctional benign adrenocortical adenoma. Only 20% of adrenal adenomas are associated with hormone hypersecretion. The most common functional lesion discovered incidentally is a cortisol-hypersecreting adenoma.

What Are the Zones of the Adrenal Gland and What Hormones Do They Produce?

Each adrenal gland has an outer cortex and an inner medulla. The cortex is composed of three zones (from outer to inner): glomerulosa, fasciculata, and reticularis. The outer zona glomerulosa is the site of mineralocorticoid (aldosterone) production. The middle zona fasciculata is the site of glucocorticoid (cortisol) production. The inner zona reticularis is the site of sex hormone (dehydroxyepiandrosterone, dehydroxyepiandrosterone-sulfate, and androstenedione) synthesis. The adrenal medulla is the location for catecholamine synthesis.

Watch Out

Remember the zones of the adrenal gland by the phrase, "The deeper you go, the sweeter it gets – salt, sugar, sex."

What Are the Physiologic Effects of Normal and Excessive Cortisol Secretion?

Cortisol binds to intracellular cytoplasmic receptors and influences transcriptional activation of genes, specifically affecting glucose metabolism, intravascular volume, and

immune modulation. The primary action of cortisol is to increase blood glucose levels via inhibition of insulin-mediated cellular glucose uptake, stimulation of glycogenolysis, stimulation of hepatic gluconeogenesis, and stimulation of peripheral proteolysis and lipolysis. Excessive cortisol secretion therefore causes hyperglycemia, muscle wasting, and fat redistribution which presents as central obesity. Cortisol also regulates intravascular volume and blood pressure by increasing renal reabsorption of sodium, raising peripheral vascular resistance, and having direct chronotropic and inotropic effects on the heart. Excessive secretion results in hypertension. Cortisol impairs cellular immunity by inhibiting cytokine production, inhibiting T-cell activation, and impairing monocyte and neutrophil chemotaxis. Hypercortisolism impairs wound healing and increases the risk of infection.

What Is the Cause of Hypertension and Hypokalemia in Hyperaldosteronism?

Aldosterone acts on the distal convoluted tubule of the kidney to increase sodium reabsorption (active process). This causes passive reabsorption of water and increases extracellular volume and blood pressure. To balance the positively charged sodium ions, potassium is excreted in the urine.

Watch Out

In cases of excess volume loss (e.g., emesis), persistent potassium excretion can lead to severe hypokalemia and arrhythmia. The kidneys begin to secrete hydrogen instead of potassium resulting in paradoxical aciduria in the context of metabolic alkalosis.

Workup

What Is the Next Step in Workup when an Adrenal Adenoma Is Suspected or Seen on Imaging?

An evaluation (■ Fig. 11.4) must be performed to determine if the adrenal mass is associated with hormone hypersecretion. A thorough history and physical should be performed, followed by biochemical analysis. Suspected *Cushing's syndrome* can be evaluated with a 24-hour urine cortisol or low-dose dexamethasone suppression test or midnight salivary cortisol. If any of these are abnormal, the next step is to order a plasma ACTH level and high-dose dexamethasone suppression test. Due to the wide circadian variability of plasma cortisol levels (highest at 8:00 a.m., lowest at midnight), a single random cortisol level is not helpful. If hyperaldosteronism is suspected, start with a plasma aldosterone/renin ratio and serum potassium. Suspected pheochromocytoma should be evaluated with a 24-hour urine/plasma metanephrines or catecholamines. If no clinical symptoms are present, sending all the above biochemical studies empirically is appropriate.

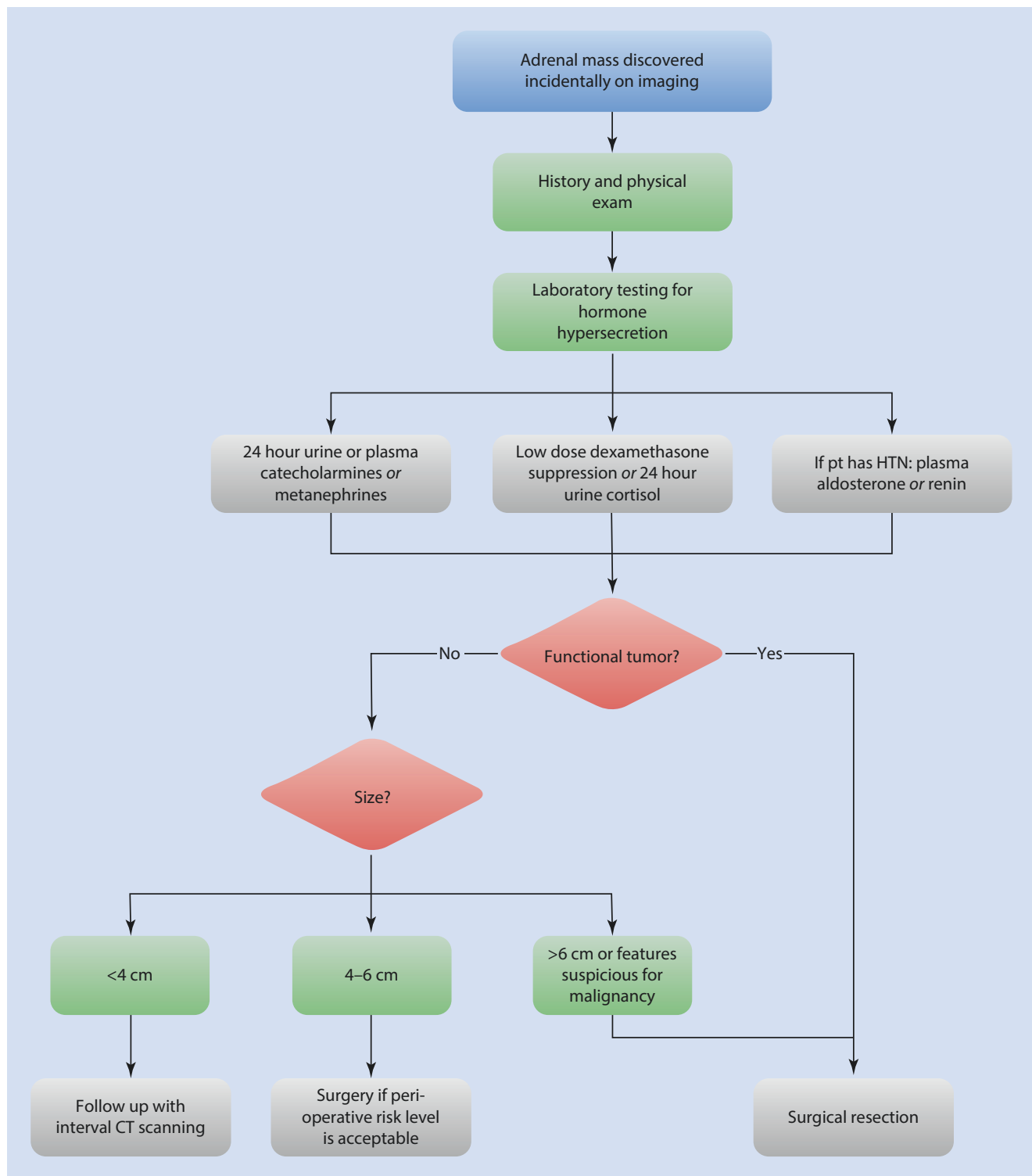


Fig. 11.4 Algorithm for workup and management of incidental adrenal mass

Watch Out

A careful medication history should be performed to examine for exogenous sources of glucocorticoids, including those contained in herbal or "alternative" supplements.

What Is the Difference Between a Low-Dose and High-Dose Dexamethasone Suppression Test?

The most sensitive test for hypercortisolism is the low-dose dexamethasone suppression test, a provocative test which involves administering 1 mg of dexamethasone (a potent,

synthetic glucocorticoid that does not interfere with cortisol measurement) orally in the evening and measuring plasma cortisol the following morning. In normal physiology, dexamethasone suppresses ACTH production by the anterior pituitary via negative feedback, thereby shutting down normal endogenous cortisol production by the adrenal glands. Hence, the serum cortisol level on the morning after dexamethasone administration should normally be suppressed to below 5 µg/dL. A level above this indicates non-suppression (disruption of negative feedback) and points toward endogenous Cushing's syndrome. Once the diagnosis of hypercortisolism is confirmed, further laboratory testing is performed to identify the cause. When normal negative feedback is intact, elevated cortisol levels should suppress ACTH production from the pituitary gland. A low plasma ACTH level (<5 pg/mL) establishes the diagnosis of ACTH-independent Cushing's syndrome due to an adrenal tumor. A normal or high plasma ACTH level establishes the diagnosis of ACTH-dependent Cushing's syndrome due to either a pituitary adenoma or an ectopic source of ACTH. A subsequent high-dose dexamethasone suppression test may differentiate between a pituitary source of ACTH, which usually suppresses, and an ectopic source of ACTH, which usually does not.

What Laboratory Testing Can Identify Hyperaldosteronism?

Patients with hyperaldosteronism generally have increased aldosterone levels (>20 ng/dL), but the most sensitive screening test is to calculate the ratio between the serum aldosterone level and the plasma renin activity (measured in ng/mL/h). Normal ratios are in the 4–10 range, while patients with hyperaldosteronism have ratios >20. An elevated ratio in a hypertensive patient indicates autonomous aldosterone secretion and normal feedback inhibition of renin release. Serum hypokalemia and increased urinary potassium excretion may also be observed. To confirm the diagnosis, inappropriate aldosterone secretion should be seen after salt loading, which can be accomplished either with oral salt tablets or intravenous infusion of normal saline. Under normal physiology, the delivery of high quantities of sodium and chloride to the distal convoluted tubule should suppress renin secretion, thereby reducing aldosterone secretion. The presence of high levels of aldosterone following salt loading demonstrates non-suppression and confirms the diagnosis of hyperaldosteronism with high specificity.

Watch Out

A patient with hypertension who requires potassium supplements (clue for hypokalemia) is suggestive of hyperaldosteronism.

What Is Adrenal Vein Sampling? What Is Its Role in Evaluating Hyperaldosteronism?

Primary hyperaldosteronism can be caused by bilateral adrenal hyperplasia or a unilateral aldosterone-secreting adenoma. Because aldosterone-secreting adenomas are usually small (1–2 cm in size), they may not be visualized on cross-sectional imaging such as CT or MRI. As the prevalence of nonfunctional adrenal nodules increases with patient age, adrenal vein sampling by central vein catheterization can be useful to confirm the functional status of an adrenal nodule. Adrenal vein sampling is recommended when the patient is being considered for adrenalectomy, and CT is equivocal or shows bilateral adrenal masses.

What Laboratory Testing Can Identify a Pheochromocytoma?

Levels of catecholamines and their metabolites (metanephrines) can be measured either as a 24-hour urine collection or as a plasma test. The 24-hour urine collection is a good screening test (very high specificity, slightly lower sensitivity). The plasma test is very sensitive but less specific and should be used when there is a high index of suspicion for pheochromocytoma.

What Is the Best Imaging Modality to Evaluate an Adrenal Nodule? What Is Another Option?

Contrast-enhanced CT scan with fine cuts is generally the preferred imaging modality. It is fast, widely available, and has excellent spatial resolution to evaluate the adrenal gland. MRI is an alternative that is comparable to CT and based on specific characteristics can help to narrow down the diagnosis.

What Imaging Characteristics Help to Differentiate a Benign from Malignant Lesion?

The following characteristics are suggestive of a benign lesion on CT scan: size <4 cm, homogeneous appearance, well-defined borders, high levels of intracellular lipid (identified as ≤10 Hounsfield units (HU) on noncontrast CT scan), rapid washout of contrast, and low amount of vascularity. Features that are more concerning for malignancy include size >6 cm, irregular borders with necrosis, calcification and/or hemorrhage within the mass, ill-defined borders with possible invasion into adjacent structures, low levels of intracellular lipid, and high vascularity.

Management

What Is the Treatment for a Nonfunctional Adrenal Mass? How Does the Size Impact Management?

The management of a nonfunctional adrenal adenoma is based on the likelihood of malignancy. Lesions smaller than 4 cm with benign imaging features have a very low risk of malignancy (<5%); these should be observed with interval CT scanning. Lesions greater than 6 cm or those with concerning imaging features should be resected (adrenalectomy). For lesions between 4 cm and 6 cm, either observation or resection is acceptable and should be decided based on patient-specific factors such as the level of perioperative risk.

What Is the Surveillance Protocol for an Adrenal Nodule that Will Not Be Resected?

There is no universally agreed upon surveillance protocol, but a reasonable follow-up strategy consists of repeat imaging at 6, 12, and 24 months, as well as repeat biochemical evaluation for hormone levels yearly for 4 years.

What Is the Treatment for a Functional Adrenal Mass?

Any functional adrenal mass should undergo adrenalectomy regardless of size, as long as the patient is medically fit to undergo an operation.

What Are Important Perioperative Management Principles?

Patients with *Cushing's syndrome* require perioperative and postoperative glucocorticoid replacement, as ACTH secretion from the pituitary can remain suppressed for months and sometimes years after surgery. These patients are therefore at risk for postoperative adrenal insufficiency. Patients with an aldosterone-secreting mass are treated with spironolactone and potassium preoperatively. Pheochromocytoma patients require preoperative alpha-blockade for 10–14 days prior to surgery and close intraoperative hemodynamic monitoring.

Watch Out

Beta-blockers should only be used after adequate alpha-blockade in patients with pheochromocytoma because unopposed alpha-receptor stimulation may result in severe vasoconstriction and malignant hypertension.

What Are the Key Surgical Principles During an Adrenalectomy?

Laparoscopic adrenalectomy is now the standard surgical treatment for most adrenal tumors, excluding those suspicious for carcinoma. The operation can be performed either transabdominally or retroperitoneally. The arterial supply of the adrenal gland is derived from branches of the inferior phrenic artery (superiorly), aorta (medially), and renal artery (inferiorly). Venous drainage from the left adrenal vein empties into the left renal vein, while the right adrenal vein empties directly into the inferior vena cava (IVC). Control of the right adrenal vein is the critical step during right adrenalectomy. Open adrenalectomy is preferable in cases of suspected malignancy. Though there is no specific size limitation for laparoscopic adrenalectomy, many surgeons choose an open approach in tumors >8 cm.

Prognosis

What Is the Prognosis of an Adrenal Adenoma?

For patients with benign lesions, the prognosis is excellent. Surgery usually brings about biochemical cure in patients with functional adenomas. Adrenalectomy for an aldosterone-secreting adenoma results in durable improvement of hypertension in 70–90% of patients.

Key Areas Where You Can Get in Trouble

What Is the Role of Percutaneous Biopsy in the Workup of an Adrenal Mass?

Percutaneous biopsy is seldom performed during the workup of an adrenal nodule. Its primary role is in determining the presence of metastatic disease in the setting of a known extra-adrenal primary malignancy. Functional tumors that have been confirmed by biochemical analysis do not require biopsy, as it would not affect management. Percutaneous biopsy should not be performed until pheochromocytoma has been excluded, as there is a risk of precipitating a massive release of catecholamines. Lesions that are suspicious for adrenocortical carcinoma should not be biopsied as histopathologic examination cannot reliably diagnose malignancy and there is a small risk of seeding the biopsy tract.

What Is Subclinical Cushing's Syndrome and How Should It Be Managed?

Subclinical Cushing's syndrome is defined as autonomous (ACTH-independent) glucocorticoid production from the adrenal gland, without obvious clinical signs of hypercorti-

solism. It is more common than overt Cushing's syndrome. These patients have a high prevalence of metabolic conditions (obesity, diabetes, and hypertension), which may be ameliorated by resection of the involved adrenal gland. Adrenalectomy is recommended in younger patients and those with biochemical evidence of hypercortisolism or patients with significant comorbid conditions that can be attributed to glucocorticoid excess.

Summary of Essentials

History and Physical

- Look for evidence of hormonal hypersecretion.

Etiology/Pathophysiology

- Most common incidentaloma is a nonfunctional benign adrenocortical adenoma.
- Most common functional incidentaloma is associated with hypercortisolism.
- Other functional adrenal masses include pheochromocytoma and aldosteronoma.
- Adrenocortical carcinoma is a rare cause of primary adrenal malignancy.
- Consider metastasis if positive history of extra-adrenal malignancy.

Diagnosis

- Hypercortisolism
 - 24-h urine free cortisol level OR
 - Low-dose dexamethasone suppression test
 - Salivary cortisol level
- Hyperaldosteronism
 - Serum aldosterone/plasma renin ratio >20
- Pheochromocytoma
 - Urine or plasma metanephrine levels
- CT scan

Management

- Functional adenoma – adrenalectomy
- Nonfunctional adenoma
 - <4 cm: observation
 - 4–6 cm: adrenalectomy if good surgical risk
 - >6 cm: adrenalectomy

Watch Out

- Do not biopsy adrenal masses.
 - Beware of short posterior adrenal vein entering IVC with right adrenalectomy.

Suggested Reading

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Fatigue, Constipation, and Depressed Mood

James X. Wu, Paul N. Frank, and Michael W. Yeh

Case Study

A 62-year-old woman presents to your office after being diagnosed with osteoporosis by her primary care physician. Her T-score is -4.2 at the lumbar spine. Further testing reveals a serum calcium level of 11 mg/dL (normal 8.5–10.5 mg/dL), phosphate level of 1.7 mg/dL (2.5–4.8 mg/dL), intact parathyroid hormone level of 83 pg/mL (15–75 pg/

mL), and elevated urinary calcium levels. She denies any previous fractures. She reports fatigue and has more difficulty concentrating than before. She denies any history of neck irradiation or family history of thyroid or parathyroid disease. She has no significant past medical or surgical history. She has no known allergies. She occasionally takes

ibuprofen for joint pain in her hands. She is a retired schoolteacher who is physically active and enjoys traveling. On review of systems, the patient reports constipation and occasional depressed mood. Physical examination demonstrates a healthy adult female; her neck is supple without masses or adenopathy.

Diagnosis

What Is the Differential Diagnosis of Hypercalcemia?

See the below table for the differential diagnosis of hypercalcemia. A commonly used mnemonic is “CHIMPANZEES.”

Watch Out

Familial hypocalciuric hypercalcemia (FHH) causes mild increase in serum calcium, similar to primary hyperparathyroidism. However, unlike primary hyperparathyroidism, FHH has low urine calcium. FHH is a benign condition due to mutations in CASR, which encodes a calcium receptor. The lack of calcium signal increases PTH level, which increases renal calcium reabsorption.

addition, this patient endorsed fatigue, constipation, and depressed mood, which are all symptoms associated with hypercalcemia.

History and Physical

What Is the Typical Presentation for Patients with Hypercalcemia?

The most common presenting symptoms prior to routine lab testing were nephrolithiasis and pathologic fractures or bone pain. The classic mnemonic was *stones, bones, groans, and moans*: kidney stones, aching bones, abdominal groans (pain), and neuropsychiatric moans. Due to current routine laboratory testing, most patients diagnosed with hypercalcemia are diagnosed much earlier and are asymptomatic or mildly symptomatic.

Watch Out

Humoral hypercalcemia of malignancy is caused by parathyroid hormone-related peptide (PTHrP) in 80% of cases (squamous cell cancers), while 20% of cases are caused by cytokines/chemokines (breast cancer).

What Is This Patient's Diagnosis?

An elevation of serum calcium combined with an elevated parathyroid hormone (PTH) level and high urinary calcium confirms the diagnosis of primary hyperparathyroidism. In

Table 12.1

Etiology	Differentiating lab finding	Comment
Calcium supplementation	None	Calcium carbonate, calcium citrate
Hyperparathyroidism	↑ or high-normal PTH	Primary hyperparathyroidism is the most common <i>outpatient</i> cause of hypercalcemia
Hyperthyroidism	↓ TSH	Leads to increased bone reabsorption
Immobility	None	Causes rapid bone turnover, usually young patients following trauma
Iatrogenic	None	Thiazide diuretics: increase calcium absorption at distal tubule
Milk-alkali syndrome	↑ HCO ₃	Excess ingestion of Ca ⁺⁺ from antacids
Paget's disease	↑ Alkaline phosphatase, ↑ serum and urine hydroxyproline	Excessive, disorganized bone remodeling
Addison's disease	↑ ACTH	Unclear, glucocorticoid deficiency may increase bone resorption
Acromegaly	↑ IGF1	
Neoplasm	↑ PTHrP	Most common cause of <i>inpatient</i> hypercalcemia; can be due to cytokines or PTHrP
Zollinger-Ellison syndrome	↑ Gastrin	Associated with multiple-endocrine neoplasm (hyperparathyroidism)

Table 12.1 (continued)

Etiology	Differentiating lab finding	Comment
Excessive vitamin D	↑ Increased vitamin D	Excess GI calcium absorption, increased bone reabsorption
Excessive vitamin A	↑ increased vitamin A	Unclear etiology
Sarcoidosis/granulomatous disease	↑ Vitamin D	Granuloma macrophages activate 25-OH vitamin D

PTH parathyroid hormone, *TSH* thyroid stimulating hormone, *ACTH* Adrenocorticotrophic hormone, *IGF1* Insulin-like growth factor 1, *PTHrP* parathyroid hormone-related protein

What Are the Renal Manifestations of Hypercalcemia?

Nephrolithiasis (most commonly men under age 60), as well as nephrocalcinosis, polyuria, polydipsia, and renal hypertension, and over time, some patients will experience a decline in renal function.

What Are the Gastrointestinal Manifestations of Hypercalcemia?

Constipation, nausea, vomiting, heartburn, and vague abdominal pain. Rarely, peptic ulcer disease and pancreatitis

What Are the Neurological Manifestations of Hypercalcemia?

Fatigue, depressed mood, difficulty concentrating, impaired memory, anxiety, sleep disturbance, proximal muscle weakness, and psychomotor symptoms. Stupor and coma may be found in cases of extreme hypercalcemia (serum calcium >14 mg/dl) or in the elderly.

What Patient Demographic Most Commonly Presents with Hyperparathyroidism?

Postmenopausal women

What Are the Risk Factors for Primary Hyperparathyroidism?

Exposure to low-dose therapeutic ionizing radiation, family history of hyperparathyroidism, and lithium therapy for bipolar disorder.

Why Is Family History Important?

Hyperparathyroidism occurs in a number of inherited diseases, such as MEN-1, MEN-2A, familial isolated hyperparathyroidism, and hyperparathyroidism-jaw tumor syndrome.

Watch Out

MEN-1 (3 Ps) consists of hyperparathyroidism, pituitary adenomas, and pancreatic neuroendocrine tumors. MEN-2A (2 Ps) is characterized by hyperparathyroidism, pheochromocytoma, and medullary thyroid cancer. MEN-2B (1 P) is characterized by marfanoid habitus, oral neuromas, medullary thyroid cancer, and pheochromocytoma.

What Is a Hypercalcemic Crisis?

Patients with severe hypercalcemia (>14 mg/dl) may present with nausea, vomiting, confusion, and mental status changes. This is a medical emergency, as severe hypercalcemia can lead to cardiac arrhythmias and coma.

What Are the Physical Exam Findings of Hyperparathyroidism? What Is the Significance of an Anterior Neck Mass Palpated in a Patient with Hyperparathyroidism?

Physical exam findings are typically not useful in hyperparathyroidism, as the great majority of enlarged parathyroid glands are soft, <2 cm in diameter, and non-palpable. An anterior neck mass in a patient with hyperparathyroidism is most commonly a thyroid nodule but can represent a parathyroid carcinoma.

What Is Chvostek's Sign?

Facial twitch in response to tapping on the facial nerve, anterior to the external auditory canal. This reflects early tetany and is a sign of hypocalcemia that may arise after parathyroidectomy.

What Is Trousseau's Sign?

The combination of flexion of the wrist and metacarpophalangeal joints and extension of the digits following inflation of a blood pressure cuff around the arm to greater than

systolic blood pressure. Similar to Chvostek's sign, this marks early tetany due to hypocalcemia.

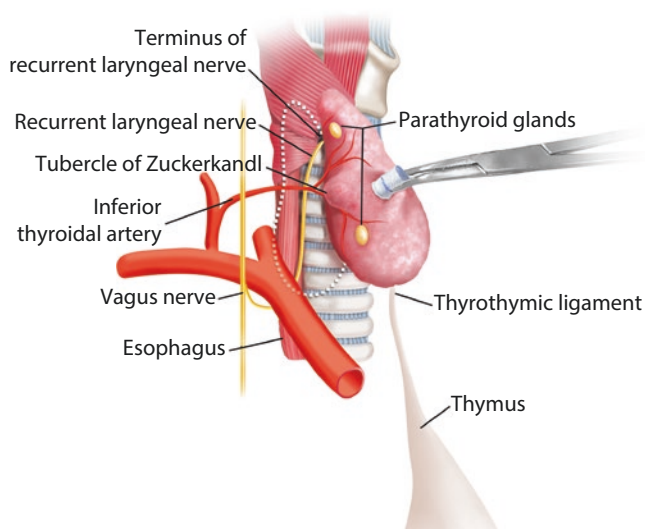
What Is T-Score?

The T-score is a test of bone density. The T-score refers to the number of standard deviations below the average for a young adult at peak bone density. Normal bone has a T-score greater than -1 . Patients with osteopenia have scores between -1 and -2.5 , whereas those with osteoporosis have a score less than -2.5 .

Anatomy

Describe the Location of the Parathyroid Glands. What Is Their Embryological Development?

There are four parathyroid glands, two superior (laterally) and two inferior (medially) (■ Fig. 12.1). The superior parathyroids develop from the fourth pharyngeal pouch and migrate in conjunction with the thyroid, which form the tubercle of Zuckerkandl. The superior parathyroid glands are very consistent in their location, with approximately 95% being located adjacent to the tubercle of Zuckerkandl, posterior to the terminus of the recurrent laryngeal nerve. The inferior parathyroid glands develop from the third pharyngeal pouch and migrate inferiorly in conjunction with the thymus. About 65% are located on the surface of the inferior aspect of the thyroid gland, with most of the remainder being found within the thyrothymic ligament or the thymus. Up to 15% of people may have more than four parathyroid glands.



■ Fig. 12.1 Parathyroid glands

Watch Out

The parathyroid glands can sometimes be hidden in the mediastinum (within the thymus), within the carotid sheath and thyroid gland or behind the esophagus.

Pathology/Pathophysiology

What Pathology Causes Primary Hyperparathyroidism? Is There a Genetic Component?

Enlargement and hypersecretion by a single (80%) adenoma or multiple (20%) parathyroid glands (either four gland hyperplasia or multiple adenomas). Primary hyperparathyroidism is more common than secondary or tertiary hyperparathyroidism, affecting more women than men. The cell population within parathyroid adenomas is monoclonal or oligoclonal. The cause is not well understood. Sporadic mutations in the menin tumor suppressor gene (that are responsible for MEN-1) have been found in parathyroid adenomas.

What Is the Typical Pathology in Primary Hyperparathyroidism Associated with the MEN Disorders?

Unlike sporadic primary hyperparathyroidism, which is usually due to a single adenoma, with MEN disorders, the gene is expressed in all glands and is thus characterized by four-gland hyperplasia.

What Is the Pathophysiology of Secondary Hyperparathyroidism?

It is usually an adaptive response to prolonged hypocalcemia from chronic kidney disease or vitamin D deficiency which leads to parathyroid hyperplasia (polyclonal expansion) with excessive PTH secretion. Serum calcium levels can be low or normal. Secondary hyperparathyroidism requiring surgery is uncommon (about 1%).

What Causes Tertiary Hyperparathyroidism?

Persistent excess secretion of PTH following renal transplantation in patients with long-standing secondary hyperparathyroidism. Renal transplantation restores normal vitamin D homeostasis and reverses secondary hyperparathyroidism in >95% of cases within 1 year. Patients with tertiary hyperparathyroidism generally manifest with hypercalcemia, inappropriate PTH level excess, and parathyroid hyperplasia. Tertiary hyperparathyroidism is rare. ■ Table 12.2 summarizes the key differences in the three types of hyperparathyroidism.

Table 12.2 Different types of hyperparathyroidism (HPT)

Condition	Ca ²⁺	PO ₄	PTH	Comments
Primary HPT	↑	↓	↑	Most often found incidentally on routine lab studies in <i>otherwise healthy</i> patients who are <i>asymptomatic</i> CI: PO ₄ >33:1
Secondary HPT	↓ or nl	↑	↑	Hypocalcemic stimulus due to poor calcium reabsorption, lack of vitamin D activation Renal transplant usually curative
Tertiary HPT	↑	↓	↑	History of corrected renal failure with transplant Adenoma formed in setting of chronic hypocalcemia with persistent PTH stimulation Hypercalcemia can harm graft function

Table 12.3 Calcium metabolism

Hormone	Stimulus	Effect on the kidney	Effect on the bone	Effect on the intestine
Parathyroid hormone	↓Ca, ↑PO ₄ , ↓1,25-OH vitamin D, mildly ↓Mg	↑1,25-OH vitamin D production, ↓tubular reabsorption of PO ₄ and HCO ₃	↑Bone resorption	–
1,25-OH vitamin D	PTH	↓Tubular reabsorption of Ca	↑Ca uptake	↑Absorption of Ca and PO ₄
Calcitonin	↑Ca, gastrin	–	↓Bone resorption	–

What Are the End Organs Affected by Parathyroid Hormone?

PTH affects the skeleton and kidneys. In the skeleton, PTH increases serum calcium by inhibiting osteoblasts from creating new bone and stimulating osteoclasts to break down the bony matrix to release additional calcium. In the kidneys, PTH increases calcium absorption and phosphate excretion. PTH also drives hydroxylation of 25-OH vitamin D to the active 1,25-OH vitamin D via the upregulation of renal 1-alpha-hydroxylase. Active vitamin D acts as a second messenger to increase calcium absorption from the gut.

What Is the Basic Physiology of Calcium Metabolism?

Calcium homeostasis in humans is principally regulated by PTH. Calcitonin, a counter-regulatory hormone that lowers the serum calcium, is very weak and has a negligible effect in humans (Table 12.3).

What Is the Most Common Cause of Parathyroid Hormone Deficiency? How Does It Manifest?

The most common cause of parathyroid hormone deficiency is iatrogenic destruction or removal of parathyroid glands at

the time of parathyroid or thyroid surgery. Autoimmune destruction of the parathyroid glands is a very rare cause. Patients with parathyroid hormone deficiency will present with *hypocalcemia* and *hyperphosphatemia* in the presence of normal renal function.

Work-Up

What Laboratory Tests Are Used for the Diagnosis of Primary Hyperparathyroidism?

Serum calcium and PTH level. Other useful tests include phosphate, chloride, bicarbonate, magnesium, serum creatinine, 24-hour urinary calcium, and 25-OH vitamin D level.

Does an Elevated PTH Level Combined With an Elevated Serum Calcium Level Establish the Diagnosis of Primary Hyperparathyroidism?

Not entirely. Urinary calcium is needed to rule out hypocalciuric hypercalcemia (FHH). FHH is rare. A high urine calcium level (hypercalciuria), with a high PTH level and high serum calcium level, confirms primary hyperparathyroidism.

What Is the Difference Between Total Serum Calcium Level and Ionized Calcium Level?

Total serum calcium is the sum of protein-bound calcium and free calcium. Ionized calcium reflects free (nonprotein bound) calcium.

If the Serum Calcium Is High, but the PTH Level Is Normal, Does That Rule Out Primary Hyperparathyroidism?

No. In the setting of high serum calcium, the PTH level should be low. An *inappropriately normal* (non-suppressed) PTH level in the setting of hypercalcemia would strongly suggest primary hyperparathyroidism. Impaired negative feedback of this kind is often diagnostic of endocrine disease.

How Can the Serum Chloride to Phosphate Ratio Suggest Primary Hyperparathyroidism?

A serum chloride to phosphate ratio >33 is highly suggestive of hyperparathyroidism. PTH acts on the kidney and increases calcium reabsorption as well as excretion of bicarbonate and phosphate. Excretion of bicarbonate results in a rise in serum chloride to balance ion charges, resulting in hyperchloremic metabolic acidosis.

Watch Out

Remember PTH's effect on phosphate by "PTH is the Phosphate Trashing Hormone."

What Other Tests Should Be Ordered in a New Diagnosis of Hyperparathyroidism?

Bone mineral density testing via dual-energy X-ray absorptiometry (DEXA) is indicated in asymptomatic patients, all postmenopausal women, and patients with a history of fragility fractures. A T-score is calculated. Patients with hyperparathyroidism often have osteopenia or osteoporosis. Renal ultrasound or abdominal plain films may be used in patients with symptoms suggestive of nephrolithiasis.

What Radiologic Findings Are Suggestive of Bony Involvement in Hyperparathyroidism?

Plain films of the hands can reveal subperiosteal cortical bone resorption, most commonly in the distal phalanges. In rare cases of advanced disease, osteitis fibrosa cystica may be



Fig. 12.2 Sestamibi scan showing a hyperactive parathyroid adenoma

found on plain films, as manifested by brown tumors – lucent areas left by overactive bone breakdown and subsequent fibrosis.

What Tests Help Localize the Involved Gland in Hyperparathyroidism?

99-m technetium sestamibi scanning (■ Fig. 12.2) and ultrasound are the most frequently used imaging tests to localize the involved gland(s) in primary hyperparathyroidism. Dynamic parathyroid CT, sometimes termed 4D-CT, is also used by some centers. Localizing studies are generally not indicated in secondary or tertiary hyperparathyroidism, since multiple-gland hyperplasia is the expected underlying pathology.

Watch Out

Sestamibi is also taken up by the thyroid tissue. Hence, a thyroid nodule can mimic the appearance of a parathyroid adenoma.

What If All Localizing Scans Fail to Localize the Abnormal Parathyroid Gland(s)?

In about 85% of patients, imaging will localize the abnormal parathyroid gland, and a great majority will have a single parathyroid adenoma. If localizing scans are negative, yet the diagnosis of primary hyperparathyroidism is clearly established, surgery should still be considered but will be technically more challenging. Hence, patients with negative imaging should be referred to an experienced surgeon for treatment.

Management

What Are the Indications for Parathyroidectomy in Primary Hyperparathyroidism?

Parathyroidectomy is indicated in patients with symptomatic hypercalcemia (kidney stone, bone, gastrointestinal, and neuropsychiatric symptoms). For patients with asymptomatic hyperparathyroidism diagnosed through a laboratory screening, a 2013 consensus statement recommended any of the following indications for surgery:

1. Serum calcium level of 1.0 mg/dL greater than the upper limit of normal
2. Creatinine clearance reduced to <60 mL/min
3. Elevated 24-hour urine calcium >400 mg/day and increased risk for calcium stone formation on biochemical stone risk analysis
4. Presence of asymptomatic nephrolithiasis or nephrocalcinosis seen on imaging
5. Bone mineral density with T-score less than -2.5 at any site
6. Evidence of vertebral fracture
7. Age <50
8. Patients that do not desire or cannot undergo routine surveillance

What Are the Indications for Parathyroidectomy in Secondary Hyperparathyroidism?

Very high PTH levels (>800 pg/ml) despite best medical management, bone pain, pruritus, progressive renal disease, fragility fractures, or calciphylaxis (calcification of soft tissues) should undergo parathyroidectomy.

What Is the Nonoperative Management of Patients with Hyperparathyroidism?

Patients not selected for surgical therapy require biochemical monitoring of serum calcium and serum creatinine annually. Bone mineral density should be measured every 1–2 years. Bisphosphonates may stabilize or improve bone mineral density. Cinacalcet, a calcimimetic, may be used to reduce the serum calcium, though it has no benefit with regard to bone density.

What Is the Role of Intraoperative PTH Monitoring?

Because of the short half-life of PTH (about 4 min), intraoperative rapid PTH testing may aid in determining the

completeness of parathyroid resection. The most commonly used protocol involves drawing PTH levels at the time of gland excision and again 10 min post-excision. A fall of >50% in the PTH level is associated with a 98% long-term cure rate.

What Are the Surgical Options for Hyperparathyroidism?

If the patient has a single enlarged parathyroid adenoma, the treatment is to remove that one enlarged gland. This is typically done with a unilateral neck exploration with excision of a solitary parathyroid adenoma (commonly performed for primary hyperparathyroidism with positive localization). If the patient has hyperplasia of all four glands, most surgeons recommend either removing 3½ of the glands or all four glands and reimplanting ½ (about 40 g) of one of the glands into the forearm muscle or into the sternocleidomastoid. This is most appropriate for patients with a high likelihood of recurrent disease, such as MEN-1.

Why Is It Advised Not to Remove All Four Parathyroid Glands?

The reason all four glands are not removed is that it usually results in permanent hypocalcemia that is very difficult to control. The reimplantation preserves some parathyroid tissue. Typically, the non-dominant forearm is favored over the sternocleidomastoid if the parathyroid tissue to be autotransplanted is abnormal. If the patient then develops recurrent hyperparathyroidism, an incision can be made in the forearm muscle under local anesthesia, and additional tissue can be removed. This avoids a reoperation in the neck.

What Is the Postoperative Management Following Parathyroidectomy?

Monitor for neck hematoma, voice changes (injury to recurrent laryngeal nerve), perioral numbness, or tingling in fingers (hypocalcemia). Routine postoperative oral calcium supplementation may alleviate minor symptoms of relative hypocalcemia and is used routinely by many expert centers. Intravenous calcium supplementation is not commonly needed.

What Is the Treatment for a Neck Hematoma with Stridor?

Immediately open neck wound at the bedside to decompress the hematoma followed by evacuation of hematoma and hemostasis in the operating room.

What Are the Benefits of Parathyroidectomy?

Successful parathyroidectomy results in sustained increases in bone mineral density at multiple sites. The risk of new kidney stone formation falls rapidly after surgery. Approximately 70% of patients experience improvements in quality of life attributed to relief of constitutional, musculoskeletal, and neuropsychiatric symptoms.

What Syndrome Causing Postoperative Hypocalcemia Can Occur Following Parathyroidectomy?

In hyperparathyroidism, high levels of parathyroid hormone cause bone to be chronically starved of calcium. Once the hyperparathyroidism has been surgically corrected, bone may voraciously absorb calcium, causing postoperative hypocalcemia (hungry bone syndrome). Bone hunger may be pronounced in cases of secondary hyperparathyroidism, particularly in patients who have been on dialysis for many years. Such patients may require prolonged hospitalization for 1 week or more postoperatively for calcium supplementation.

Areas of Controversy

Surgery Versus Observation in Asymptomatic Hyperparathyroidism

Two competing consensus statements regarding surgical treatment of asymptomatic/minimally symptomatic patients have been published. The more commonly accepted international consensus guidelines, updated in 2013, recommend surgery for select patients meeting certain criteria (see *Management*, above). Approximately 40% of patients with primary hyperparathyroidism meet one or more criteria, less than half of whom undergo surgery in community practice. The second set of guidelines, published by the American Association of Endocrine Surgeons (AAES), stresses that surgery is more cost-effective than long-term observation or medical management. The AAES guidelines recommend surgery in patients with acceptable perioperative risk who have neurocognitive symptoms attributable to hyperparathyroidism and recommend considering surgery in patients with cardiovascular disease and in patients with nontraditional symptoms (muscle weakness, abnormal sleep patterns, gastroesophageal reflux disease, fibromyalgia).

Focused/Unilateral Exploration Versus Four-Gland Exploration, Use of Intraoperative PTH Testing

Prior to the advent of localizing studies, four-gland exploration was routinely undertaken after the biochemical diagnosis of primary hyperparathyroidism was made. Starting in the mid-1980s, accurate localization with sestamibi scanning and ultrasound drove the increasing application of focused or unilateral exploration over three decades, yielding high cure rates >95% in expert hands. Recently, long-term follow-up of large patient populations treated in expert centers has raised the question of whether focused/unilateral exploration results in a higher late recurrence rate compared with four-gland exploration.

Areas Where You Can Get in Trouble

Assuming Normal Calcium Rules Out Hyperparathyroidism

Total calcium levels can be affected by serum albumin. A malnourished patient with low serum albumin can have a falsely low total calcium level. The formula for correction is $\text{corrected Ca} = \text{serum Ca} + [(0.8) (4.0 - \text{serum albumin})]$. Alternatively, serum ionized calcium can be measured, which is unaffected by albumin. However, ionized calcium is affected by blood pH. When pH is low (acidosis), there is a decreased protein binding, increasing serum ionized calcium.

Hypocalcemia That Does Not Respond to Calcium Replacement

If a patient with hypocalcemia does not respond to calcium repletion, check the magnesium level. Hypomagnesemia can cause refractory hypocalcemia by inhibiting the bioactivity of PTH.

Special Situations

How Do You Treat Hypercalcemic Crisis?

Aggressive infusion of normal saline is the first line of therapy. Hypercalcemic patients are often volume depleted, since the hypercalcemic state impairs the kidney's ability to concentrate urine. Normal saline infusion replaces this lost volume and reduces the serum calcium through dilution. After the

patient has been rendered euvolemic, *loop diuretics*, which cause calciuresis, may be added. Newer studies suggest that in patients with normal heart and kidney function, loop diuretics may not be indicated and calcitonin be used instead. *Bisphosphonates*, such as pamidronate or the more potent zoledronate, can also help by binding hydroxyapatite in bone and blocking osteoclast activity. Bisphosphonates should typically only be used in hypercalcemia of malignancy. Any

drugs that may worsen hypercalcemia (e.g., thiazide diuretics) or exacerbate symptoms of hypercalcemia (digoxin potentiates arrhythmias in hypercalcemia) should be immediately discontinued. If the etiology is determined to be primary hyperparathyroidism, patients should undergo urgent parathyroidectomy. Hemodialysis may be used in rare cases in the presence of renal failure or to acutely lower the serum calcium level.

Algorithm for the Work-Up and Management of Hyperparathyroidism (Figs. 12.3 and 12.4)

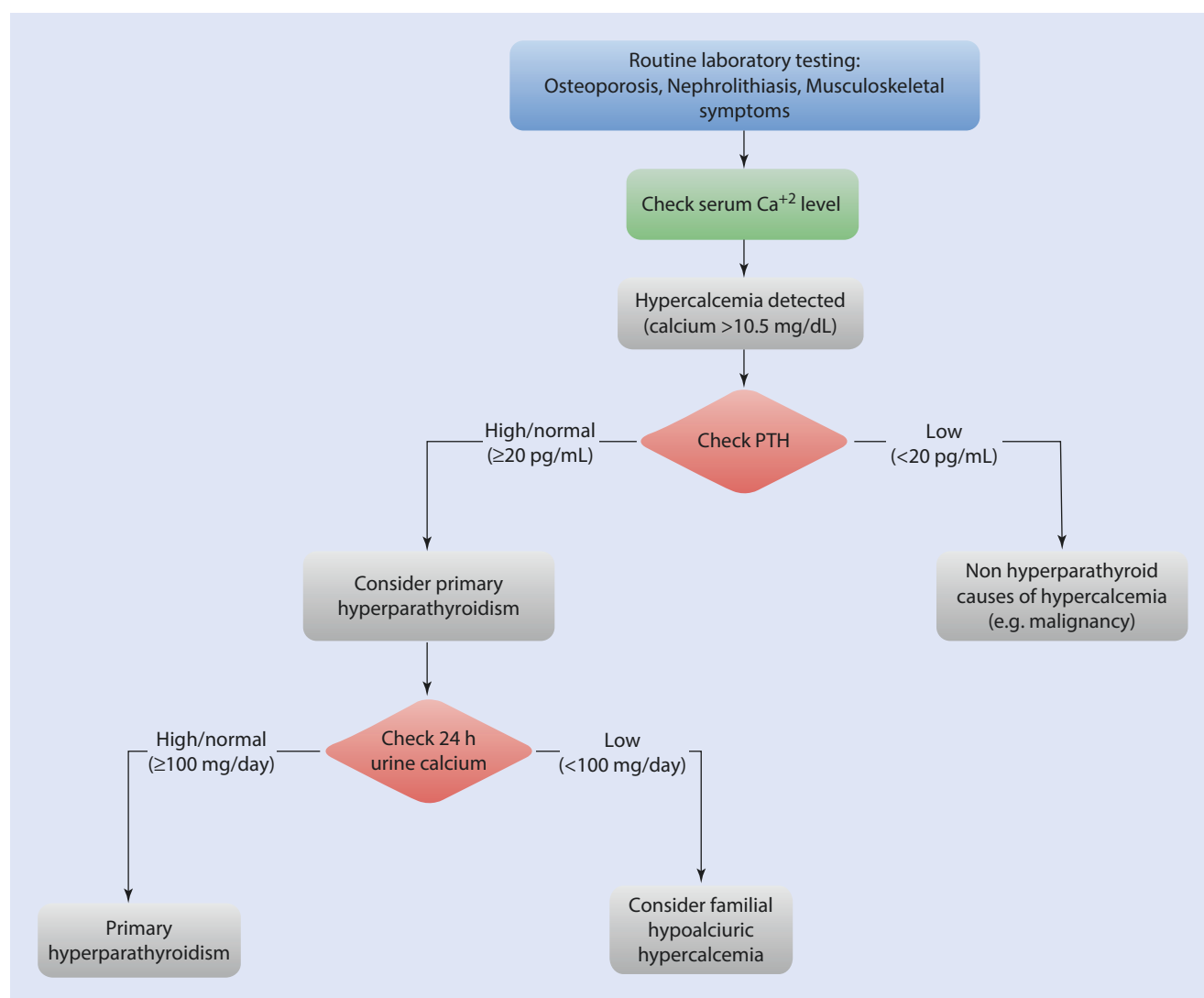


Fig. 12.3 Diagnostic algorithm for primary hyperparathyroidism

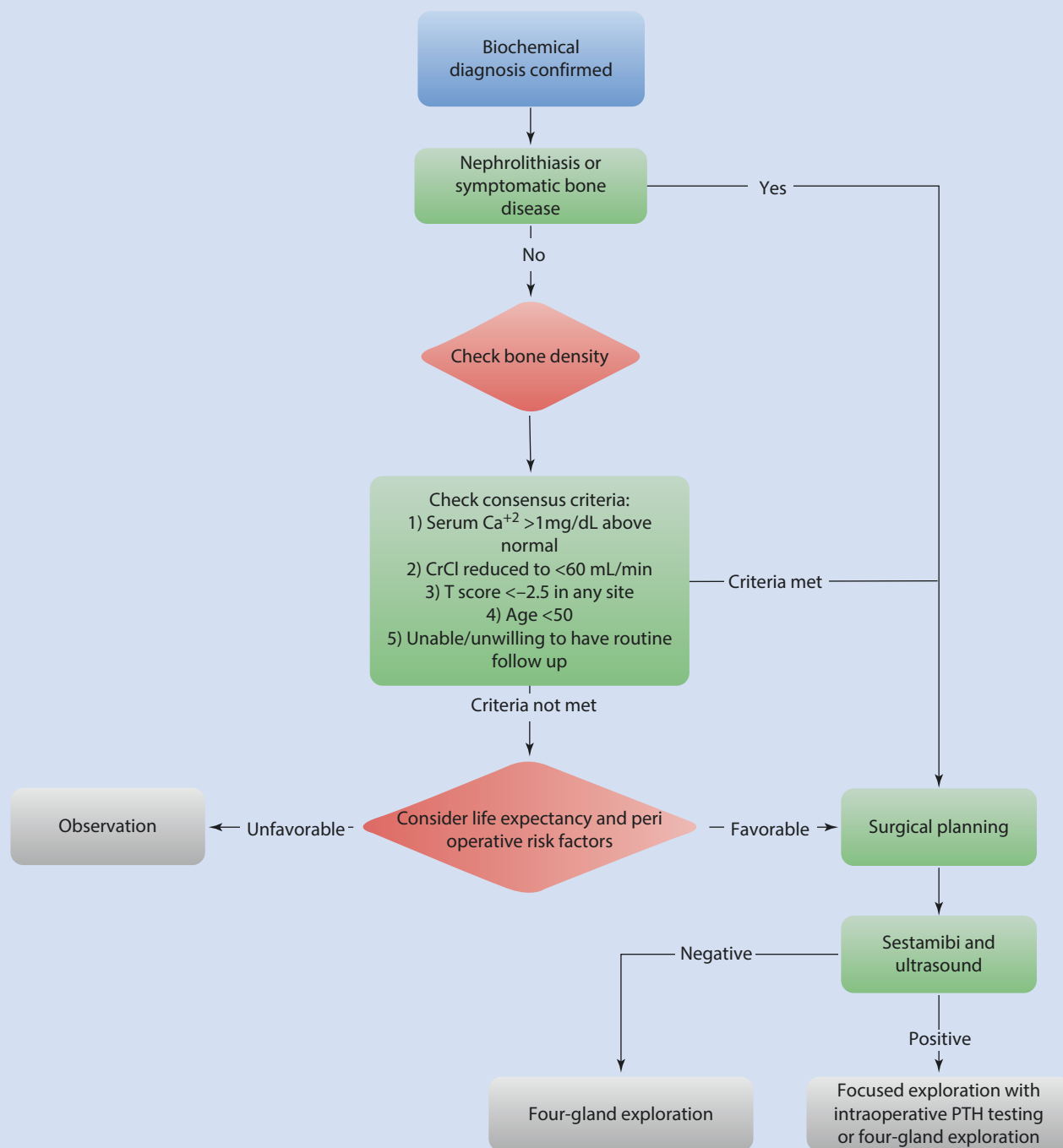


Fig. 12.4 Management algorithm for primary hyperparathyroidism

Summary of Essentials

History and Physical

- Symptoms of HPT: stones, bones, groans, and moans
- Differential of hypercalcemia: CHIMPANZEES

- Primary hyperparathyroidism is caused by excess PTH secretion, leading to hypercalcemia and osteopenia
- The majority of patients are asymptomatic and discovered after incidental hypercalcemia is found during routine chemical panels
- The most common outpatient cause of hypercalcemia is primary HPT; the most common inpatient cause is malignancy

Diagnosis

- Primary hyperparathyroidism: elevated calcium with high or inappropriately normal PTH level
- Secondary hyperparathyroidism: decreased serum calcium with increased intact PTH most often seen with renal disease (also vitamin D deficiency)
- Obtain bone densitometry in asymptomatic patients

Pathophysiology

- PTH affects the bones and kidneys directly, increasing bone breakdown and calcium absorption and vitamin D activation in the kidneys
- Vitamin D increases calcium absorption in the gut

Management

- Indication for parathyroidectomy in asymptomatic patients with primary HPT:
 - Serum calcium level 1.0 mg/dL greater than the upper limit of normal
 - Creatinine clearance reduced to <60 mL/min
 - Elevated 24-hour urine calcium >400 mg/day and increased risk for calcium stone formation on biochemical stone risk analysis
 - Presence of asymptomatic nephrolithiasis or nephrocalcinosis seen on imaging
 - Bone mineral density with T-score less than -2.5 at any site
 - Evidence of vertebral fracture
 - Age <50
 - Patients that do not desire or cannot undergo routine surveillance

- Indication for parathyroidectomy in secondary HPT: high PTH level despite medical management, bone pain, pruritus, progressive renal disease, osteopenic fractures, and calciphylaxis
- Localize PTH adenoma with sestamibi scan and ultrasound

Watch Out

- Primary HPT is most commonly caused by single parathyroid adenoma, but multiple-gland parathyroid disease is present in 10–15% of patients.
 - The parathyroid glands are variable in their location; successful surgery depends on the knowledge of the anatomy and embryology of the parathyroids.

Suggested Reading

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Intermittent Episodes of Sweating, Palpitations, and Hypertension

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Case Study

A 34-year-old woman presents with a chief complaint of what she calls “rushes,” intermittent episodes of sweating, headaches, and palpitations lasting for a few minutes and occurring sporadically every few days. These episodes can occur at any time of day and have sometimes awakened her from sleep. She notes that exercise may provoke her symptoms. Past medical history is significant for newly diagnosed hypertension. Her physical exam is remarkable only for hypertension, with a blood pressure of 165/100 mmHg. Her biochemical workup reveals an elevated 24-hour urine metanephrine (1163 mcg/day; normal <400 mcg/day). A dedicated adrenal protocol CT scan shows a 4-cm mass in the right adrenal gland with central cystic change.

Diagnosis

What Is the Differential Diagnosis and What Clues on History and Physical Examination Might Direct You Toward a Specific Diagnosis?

Table 13.1

Diagnosis	History and physical	Comments
<i>Pheochromocytoma</i>	Episodic hyperadrenergic symptoms (5 P's): pressure (hypertension), pain (headache), perspiration, palpitation, pallor	Associated with MEN 2, neurofibromatosis-1, and VHL
<i>Carcinoid syndrome</i>	Bronchospasm, diarrhea, flushing of skin, and right-sided heart disease; symptoms triggered by alcohol or emotional stress	Excess serotonin release, malignant proliferation of neuroendocrine cells, most commonly arise from the small bowel; requires liver metastasis or extra-GI tumor for carcinoid syndrome
<i>Fibromuscular dysplasia</i>	Severe hypertension in a young female	Renal artery has “string-of-beads” appearance due to medial thickening alternating with stenosis; also affects carotid, superior mesenteric, and external iliac arteries
<i>Panic attack</i>	Intense fear or feeling of impending doom, palpitations, perspiration, and hyperventilation	Associated with mitral valve prolapse
<i>Hyperthyroidism</i>	Anxiety, emotional lability, weakness, tremor, palpitations, heat intolerance, perspiration, and weight loss despite increased appetite	Decreased TSH, increased TH
<i>Migraine</i>	Pulsatile, unilateral headache, with nausea/vomiting; some associated with aura (photopsia, paresthesia, numbness)	Can mimic stroke
<i>Coarctation of the aorta</i>	Hypertension in the arms but not the legs, weak femoral and pedal pulses	Turner syndrome, aortic valve pathology
<i>Insulinoma</i>	<i>Whipple's triad</i> : hypoglycemia, symptoms of hypoglycemia (tremulousness, palpitations, perspiration, and anxiety), and improvement after carbohydrate load	Tumor of pancreatic beta cells; MEN 1; 90% benign; this is the most common functional (endocrine) pancreatic tumor
<i>Drug induced</i>	Combination of MAOI with decongestants, sympathomimetics Illicit drugs including phencyclidine, LSD, and cocaine	Never give β -blockers to patients using cocaine (can lead to vasoconstrictive angina due to unopposed alpha-receptor stimulation)

VHL von Hippel-Lindau disease, TSH thyroid stimulating hormone, TH thyroid hormone, MEN multiple endocrine neoplasia, MAOI monoamine oxidase inhibitors

What Is the Most Likely Diagnosis?

In a patient with newly discovered hypertension coupled with reports of episodes where she experiences sweating, flushing, and palpitations lasting for a few minutes, the most likely diagnosis is a catecholamine surge secondary to pheochromocytoma. This is further supported by the biochemical workup confirming elevated urine metanephrine levels and a CT scan showing a mass in the right adrenal gland.

History and Physical

What Is the Differential Diagnosis for Surgically Correctable Hypertension (HTN)?

Although most *causes* of HTN are due to essential or primary (idiopathic) HTN, it is important that the clinician be aware that 5% of patients with HTN are due to secondary causes and are often surgically correctable. These include pheochromocytoma, cortical adrenal adenomas that produce cortisol or aldosterone, renal artery fibromuscular dysplasia, and aortic coarctation.

What Is the Classic Triad of Symptoms in Pheochromocytoma?

The classic triad of symptoms is headache, flushing, and palpitations. Though only a minority of patients has all three of these symptoms, 90% have at least one.

What Are the Other Symptoms of Pheochromocytoma?

The symptoms of pheochromocytoma derive from the systemic effects of excess catecholamines. The vast majority of patients with pheochromocytoma have either sustained or paroxysmal hypertension, often resistant to standard medical therapy. Other symptoms include anxiety, impaired gastrointestinal motility, orthostatic hypotension, weight loss, and hyperglycemia. Important cardiovascular sequelae consist of myocardial infarction, arrhythmias, stroke, and less commonly heart failure.

Watch Out

Hypertension associated with pheochromocytoma can be paroxysmal or can have fluctuations superimposed on *constantly* elevated blood pressure. This is dependent on whether catecholamines are released continuously or in shorter bursts.

Why Do Some Patients Have Orthostatic Hypotension?

Orthostatic hypotension is seen in up to 50% of pheochromocytoma patients, which may reflect a low intravascular volume. In addition, patients with pheochromocytoma may have desensitized adrenergic receptors from long-term exposure to large amounts of catecholamine. This can compromise the normal baroreceptor reflex responsible for vasoconstriction upon standing from a supine position, resulting in orthostatic hypotension.

Can Patients with Pheochromocytoma Be Asymptomatic?

With the increasing use of CT scans, upward of 25% of pheochromocytoma cases are now diagnosed incidentally during imaging for unrelated disorders. About 5% of incidentally discovered adrenal nodules are pheochromocytomas.

What Is the Average Age of Diagnosis? Is There a Gender Predisposition?

Patients are usually diagnosed at age 40–50 years. There is an equal incidence of cases in males and females.

What Is the “Rule of Tens,” and Is It Still True?

The “rule of tens” regarding pheochromocytoma (10% bilateral, 10% extra-adrenal, 10% familial, 10% multifocal, 10% malignant) was taught to generations of medical students. It was ultimately disproved in the year 2000 after a series of reports described novel germline mutations causing pheochromocytoma. We now recognize that 20–40% of pheochromocytomas arise as a result of an underlying familial syndrome and that clear genotype-phenotype correlations exist (■ Table 13.2).

In a Young Patient with Hypertension, Why Is It Important to Check Blood Pressure in Both the Arms and Legs?

If arm pressures are 20 mmHg greater than the legs, this is concerning for coarctation of the aorta or narrowing of the aorta. The infantile form is associated with patent ductus arteriosus (PDA), while the adult form is not. Patients present with hypertension in the upper extremities and hypotension with weak pulses in the lower extremities. It occurs more frequently in patients with Turner syndrome and bicuspid aortic valves.

Table 13.2 Hereditary syndromes associated with pheochromocytoma

Syndrome	Gene mutation (function)	Clinical phenotype	Pheo characteristics	Risk ^a (%)
<i>MEN 2A</i>	RET (proto-oncogene)	Medullary thyroid cancer, primary hyperparathyroidism	Benign, bilateral or multicentric; intra-adrenal	50
<i>MEN 2B</i>	RET (proto-oncogene)	Medullary thyroid cancer, marfanoid habitus, mucosal neuromas	Benign, bilateral or multicentric; intra-adrenal	50
<i>NF type 1 (von Recklinghausen's disease)</i>	NF1 (negative regulator of ras oncogene pathway)	Neurofibromas, café au lait spots, Lisch nodules (benign iris hamartomas)	15% malignant; intra-adrenal	1–5
<i>von Hippel-Lindau (VHL)</i>	VHL (tumor suppressor)	Retinal angioma, CNS hemangioblastoma, renal cell cancer, PNET, pancreatic and renal cysts	Benign, bilateral; younger age at diagnosis	10–20
<i>Paraganglioma syndromes 1–5</i>	SDHx (tumor suppressor)	Renal cell, thyroid carcinoma, gastrointestinal stromal tumor	Multiple, intra- and extra-adrenal, in SDHB 50% malignant	30–50

MEN multiple endocrine neoplasia, *NF* neurofibromatosis, *VHL* von Hippel-Lindau, *CNS* central nervous system, *PNET* pancreatic neuroendocrine tumor, *SDHx* succinate dehydrogenase

^alifetime risk of pheochromocytoma

Pathophysiology

What Is a Pheochromocytoma?

A pheochromocytoma is a catecholamine-producing tumor that is derived from chromaffin cells in the adrenal medulla or sympathetic ganglia. Extra-adrenal catecholamine-producing tumors are sometimes referred to as “paragangliomas.”

What Are the Effects of Normal and Excessive Catecholamine Secretion?

Table 13.3

Receptor	Normal function	Excessive function
α_1	Smooth muscle contraction, gluconeogenesis, glycogenolysis	Hypertension, hyperglycemia
α_2	Smooth muscle contraction, platelet aggregation	Pallor
β_1	Chronotropic, inotropic, sweat glands	Tachycardia, sweating
β_2	Smooth muscle relaxation	Hypotension

Watch Out

Paragangliomas in the neck are very rarely biologically active. Those involving the carotid sinus are called carotid body tumors.

What Are the Predominant Catecholamines in Adrenal and Extra-Adrenal Tumors?

Norepinephrine, epinephrine, and dopamine are the three biologically active catecholamines produced by pheochromocytomas. The predominant catecholamine produced varies depending on the local expression of particular catecholamine synthesis enzymes. Most intra-adrenal pheochromocytomas produce both epinephrine and norepinephrine, with norepinephrine being the predominant catecholamine. About 30% of intra-adrenal pheochromocytomas produce only norepinephrine. Epinephrine-secreting pheochromocytomas can also arise extra-adrenally from the organ of Zuckerkandl. Phenylethanolamine N-methyltransferase (PNMT), the enzyme that converts norepinephrine to epinephrine, is primarily present only in the adrenal medulla and organ of Zuckerkandl. Therefore, pheochromocytomas outside of these locations produce predominantly norepinephrine and little or no epinephrine. Dopamine-secreting tumors are rare but usually found in extra-adrenal pheochromocytomas.

Watch Out

Dopamine-secreting tumors usually do not present with hypertension. Instead, these patients have watery diarrhea which reflects the effect that dopamine has on the gastrointestinal tract. Additionally, these tumors can have co-secretions such as vasointestinal peptide which can exacerbate watery diarrhea.

Where Do Pheochromocytomas Develop?

The vast majority arise in the adrenal medulla. However, they can develop anywhere along the sympathetic nervous system

between the base of the skull and the bladder. The most common extra-adrenal locations are in the abdomen (75%), bladder/prostate (10%), thorax (10%), and head/neck (5%). Of those in the abdomen, the majority are located at the organ of Zuckerkandl.

Watch Out

The organ of Zuckerkandl is located on the abdominal aorta located near the origin of the inferior mesenteric artery and bifurcation of the iliac arteries.

What Can Trigger a Hypertensive Crisis in Pheochromocytoma?

Catecholamine release may be caused by changes in blood flow, physical stimulation, tumor necrosis, and certain drugs including sympathomimetics (both legal and illegal) and anesthetic agents. Endotracheal intubation, foods containing tyramine, abdominal trauma, surgical manipulation, emotional stress, micturition (with bladder paragangliomas), and attempts at biopsy are all known to stimulate catecholamine release from pheochromocytomas. Biopsies are generally not advised.

Why Do Patients with Pheochromocytoma Have Elevated Hematocrit Levels?

The chronic alpha constriction in patients with pheochromocytoma leads to volume depletion and hemoconcentration. Additionally, paraneoplastic production of erythropoietin (EPO) leading to high hematocrit levels may be associated with pheochromocytoma.

Why Do Patients With Pheochromocytoma Have Hyperglycemia?

Catecholamines are potent stimulators of hepatic glucose production and inhibitors of insulin secretion and action, leading to elevated serum glucose.

What Defines a Malignant Pheochromocytoma?

The presence of local invasion into adjacent organs (e.g., kidney, liver, vessels) or distant metastases to nonchromaffin sites (liver, lungs, bone) defines a malignant pheochromocytoma. This occurs in 5–10% of sporadic cases and upward of 30% of inherited cases (most notably those attributed to *SDHB* mutations). In contrast to most other tumor types, the determination of malignancy cannot be made by histopathologic analysis of the primary tumor, as cytologic atypia, high mitotic count, presence of necrosis, and even microscopic vascular invasion can occur in tumors with benign clinical behavior. Hence, the diagnosis of malignant pheochromocytoma rests on surgical assessment of invasion and often radiologic identification of metastases.

Workup

What Laboratory Tests Can Help Establish the Diagnosis of Pheochromocytoma?

Levels of catecholamines (epinephrine, norepinephrine, dopamine) and their metabolites (metanephrine, normetanephrine, vanillylmandelic acid) can be measured in the urine or blood. Twenty-four-hour urine testing is the gold standard, and a result that exceeds twice the upper limit of normal is considered positive. Many patients with hypertension will have slightly elevated levels of catecholamines that are not indicative of pheochromocytoma. Plasma-free metanephrine is highly sensitive for pheochromocytoma. Plasma chromogranin A is released from neuroendocrine cells and is elevated in the majority of patients with pheochromocytoma. It is non-specific (i.e., it can be elevated in other conditions) but can help confirm the diagnosis.

Is Urine or Plasma Testing More Reliable?

Establishing the diagnosis of pheochromocytoma can be challenging, since it is a rare diagnosis with a very large screening potential population (hypertensive patients with suggestive symptoms). Therefore, unless a highly specific test is used, false-positive test results will greatly outnumber true-positive test results. A 24-hour urine collection for catecholamines and fractionated metanephrines has a very high specificity (98%) but slightly lower sensitivity (90%). This is generally performed twice. Plasma-free metanephrine testing is slightly more sensitive (97%) but less specific (85%); hence it can be used to rule out pheochromocytoma when negative but must be confirmed by urine testing when positive results are noted. Additionally, the patient should be in a supine position when collecting blood samples to avoid false-positive results.

What Medications Can Interfere with Urine or Plasma Testing?

The following medications can cause false elevations of catecholamines: beta-blockers, decongestants, antidepressants (notably tricyclics, monoamine oxidase inhibitors, and venlafaxine), and antipsychotics (notably clozapine). Whenever possible, interfering medications should be discontinued for 2 weeks prior to biochemical testing for pheochromocytoma.

What Imaging Studies Are Helpful in Making the Diagnosis?

First-line imaging consists of CT (■ Fig. 13.1) or MRI with contrast, which have high sensitivity and can detect tumors as small as 1 cm. Nuclear imaging with

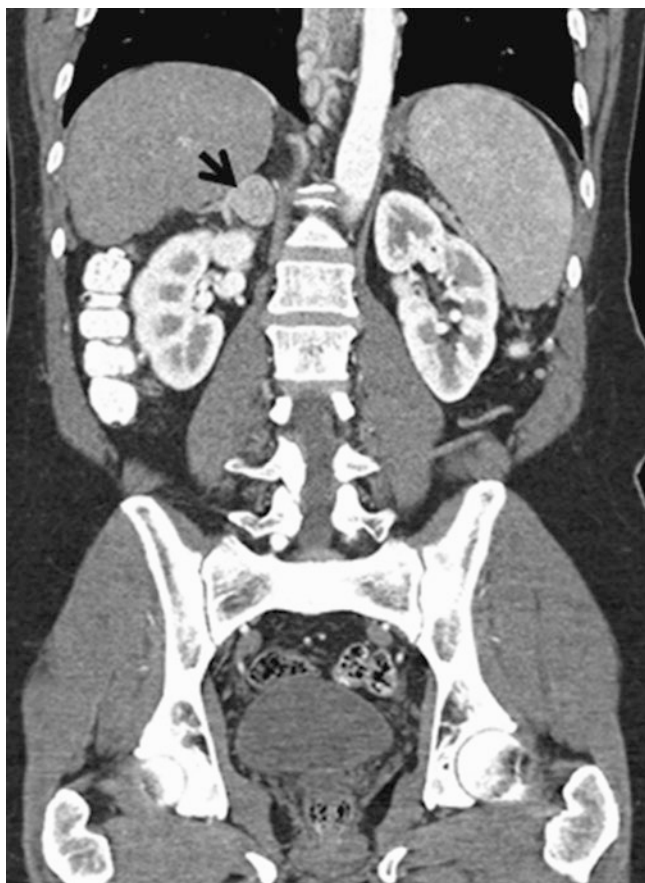


Fig. 13.1 Coronal CT with an enhancing adrenal nodule consistent with pheochromocytoma

iodine-metaiodobenzylguanidine (I-MIBG), a catecholamine precursor that is taken up by chromaffin cells, is highly specific for pheochromocytoma and may be useful in cases of suspected multifocal disease or when not well visualized on CT or MRI.

Management

What Is the Treatment for Pheochromocytoma?

Treatment (**Fig. 13.2**) consists of medical conditioning with alpha-blockade and sometimes beta-blockade for at least 2 weeks, followed by surgical resection (adrenalectomy). Surgery is usually curative, except in malignant cases.

Watch Out

Pheochromocytoma tumors need to be treated and removed first before addressing other simultaneous tumors in patients with MEN 2A/B.

What Are the Important Surgical Principles?

The laparoscopic approach is preferred for patients with adrenal pheochromocytomas that are less than 8 cm in size and have no malignant features on imaging. The operation can be performed either transabdominally or retroperitoneally. The arterial supply of the adrenal gland comes from the aorta, renal artery, and inferior phrenic artery. Venous drainage is generally from a single adrenal vein, which drains into the renal vein on the left side. On the right side, a short adrenal vein drains directly into the posterior aspect of the inferior vena cava (IVC). As such, ligation of the right adrenal vein is more difficult. The operation should be completed with minimal and very gentle handling of the tumor, so as to avoid intraoperative catecholamine surges. Effective communication between the surgical team and the anesthesia team is essential, and an anesthesiologist with experience in pheochromocytoma management is highly recommended. Well-conditioned patients are generally straightforward to manage hemodynamically. Ligation of the adrenal vein should be performed *early* and *prior* to ligation of the adrenal artery to prevent spillage of catecholamines during tumor manipulation and provide prompt resolution of hypertension. However, vein ligation may, in some cases, bring about some degree of hypotension, requiring isotonic fluids and/or vasopressin for blood pressure support.

How Do You Prepare a Patient for Surgery?

Alpha-blockade with phenoxybenzamine is initiated 2 weeks prior to surgery. It is titrated up until blood pressure is optimally controlled, resulting in mild orthostatic hypotension. This allows time for patients to restore their preexisting contracted plasma volume, ensuring that patients are not volume depleted going into surgery. For the same reason, patients are encouraged to consume a high salt and fluid diet to ensure adequate volume status. A beta-blocker can be added for patients who develop tachycardia after adequate alpha-blockade.

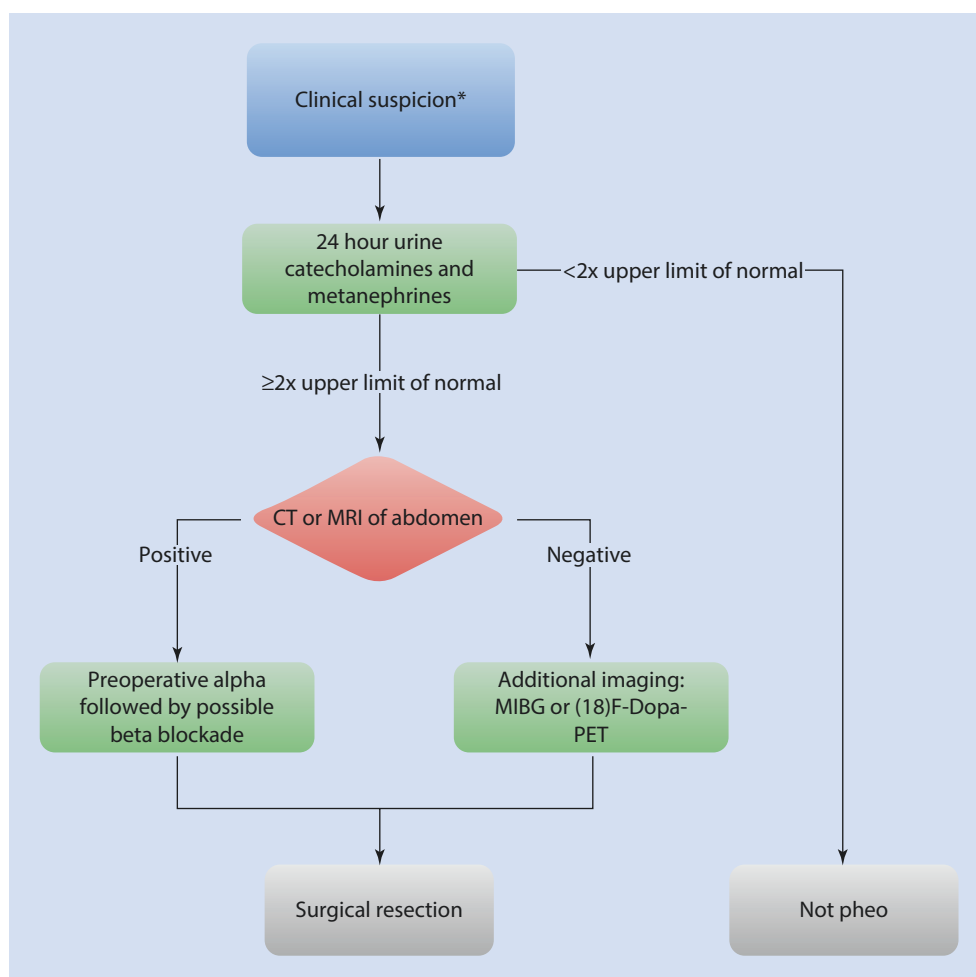
What Can Happen If a Beta-Blocker Is Given Prior to Adequate Alpha-Blockade?

The unopposed alpha-adrenergic stimulation from the pheochromocytoma can cause vasoconstriction and precipitate a hypertensive crisis. For this reason, alpha-blockers are always administered first.

When Is Genetic Testing Indicated?

Genetic testing is currently recommended for all patients with pheochromocytoma or paraganglioma. This can generally be performed after surgical treatment, through referral to a genetic counselor.

Fig. 13.2 Algorithm for diagnosis and treatment of pheochromocytoma (*Paroxysmal symptoms, intermittent or sustained hypertension, family history, or adrenal mass seen on imaging)



What Are the Main Complications Specifically Associated with Adrenalectomy for Pheochromocytoma?

Table 13.4

Complication	Features
Hypertension	May be due to residual tumor, metastatic disease, or underlying essential hypertension
Hypotension	Loss of catecholamine-induced peripheral vasoconstriction, +/- residual effects of preoperative alpha-blockade; may require vigorous fluid hydration postoperatively
Hypoglycemia	Disinhibition of insulin secretion and peripheral action of insulin; symptoms may be masked by beta-blockade; monitor serum glucose closely
Arrhythmia	Can result from hypertensive crisis

Watch Out

Patients undergoing bilateral adrenalectomy (typically due to malignancy) are at risk for Addisonian crisis and can develop severe postoperative hypotension, fever, and/or hypoglycemia. Check plasma ACTH and start IV dexamethasone.

How Often Should Plasma and Urinary Catecholamines Be Measured Postoperatively?

These should first be measured 2 weeks after surgery. If they remain high, the patient may have a residual or metastatic tumor present. Monitoring should be continued every 3 months for the first year and then annually afterward. This applies to normotensive and hypertensive patients.

Prognosis

What Is the Overall Prognosis for Pheochromocytoma?

Surgical resection is usually curative and results in normalization of blood pressure. The likelihood of malignant, multifocal, or recurrent disease varies largely as a function of the underlying genotype, since a large fraction of cases are syndromic.

What Is the Treatment for Malignant Pheochromocytoma?

There is currently no cure, and treatment is mainly directed toward palliation of symptoms. Blood pressure is controlled with alpha-blockers. Surgical debulking is often performed and can help to ameliorate symptoms and reduce the toxic effects of high circulating catecholamines on the heart and other organs.

Key Areas Where You Can Get in Trouble

Do Not Biopsy a Pheochromocytoma

The discovery of an adrenal mass on cross-sectional imaging may tempt physicians to biopsy the mass. This is ill-advised, as biopsies of the adrenal gland are generally non-informative and may be dangerous. Biopsy of an undiagnosed pheochromocytoma may result in a hypertensive crisis. The first step when an adrenal mass is found or pheochromocytoma is suspected is to perform a biochemical workup.

Pheochromocytoma and Pregnancy

Pheochromocytoma is a rare cause of hypertension in pregnancy and has a similar clinical presentation to that of the general population. This may be difficult to distinguish from preeclampsia or pregnancy-induced hypertension. The diagnosis is made with laboratory testing, and the imaging of choice is MRI to prevent fetal radiation exposure. Medical management includes alpha-blockade followed by beta-blockade if necessary. The optimal timing of surgery is controversial. Laparoscopic adrenalectomy is considered when the diagnosis is made early in gestation, preferably during the second trimester. If discovered later in pregnancy, delivery should be by cesarean section once the fetus is viable and may be accompanied by tumor resection.

Hypertensive Crisis During Surgery Due to Undiagnosed Pheochromocytoma

It is mandatory to work up any known adrenal nodule prior to elective surgery to rule out pheochromocytoma. If a patient has unexplained severe hypertension and tachycardia intraoperatively, the diagnosis of pheochromocytoma should be considered. Blood pressure should be managed with intravenous antihypertensive drips and volume repletion. In elective cases, the operation should be terminated after stabilizing the patient.

Summary of Essentials

History and Physical

- Look for episodic hyperadrenergic symptoms (5 P's): pressure (hypertension), pain (headache), perspiration, palpitation, and pallor
- Associated with the MEN 2A/B disorders, neurofibromatosis-1, VHL and familial paraganglioma syndromes

Etiology/Pathophysiology

- Tumor derived from chromaffin cells in the adrenal medulla or sympathetic ganglia
- Norepinephrine is the predominant catecholamine (followed by epinephrine)
- Triggers of hypertensive crisis include changes in blood flow, physical stimulation, tumor necrosis, anesthetic agents, foods containing tyramine, and surgical manipulation
- Malignancy based on presence of local invasion or metastasis, not cellular features

Diagnosis

- Urine and/or blood levels of catecholamines (epinephrine, norepinephrine, dopamine) and their metabolites
 - Plasma-free metanephrine is most sensitive but has higher false positives
- First-line imaging consists of CT or MRI with contrast
- Nuclear imaging with iodine-metaiodobenzylguanidine (I-MIBG) is highly specific for pheochromocytoma and may be useful in cases of suspected multifocal disease or those not visualized on CT or MRI

Management

- Medical conditioning with alpha-blockade for at least 2 weeks
- Add beta-blockade for tachycardia and/or arrhythmia
- Surgical resection (adrenalectomy) is curative
 - Laparoscopic approach is preferred for patients with adrenal pheochromocytomas that are less than 8 cm in size and have no malignant features on imaging

Watch Out

- Don't biopsy adrenal masses
- Never give beta-blocker first (unopposed alpha constriction)

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Neck Mass that Moves with Swallowing

James X. Wu and Michael W. Yeh

Case Study

A 53-year-old woman is referred to your clinic with a chief complaint of a neck mass and a hoarse voice. She sought care after feeling a lump in the lower anterior neck, just right of the midline. She complains of a sensation of neck tightness, especially when lying supine. She denies any voice changes, difficulty swallowing, or pain. She denies exposure to ionizing radiation. She takes no

medications and has no known drug allergies. Her social history is negative for tobacco and alcohol use. She does not have a family history of neck tumors or thyroid problems. On physical exam, she is a well-nourished normal adult female with a solitary, 2 cm nodule in the right lobe of the thyroid that moves with swallowing. There is no associated cervical adenopathy.

Laboratory tests demonstrate a thyroid-stimulating hormone (TSH) of 2 mIU/L (normal 0.4–4 mIU/L) and normal serum free thyroxine (T4) and free triiodothyronine (T3) levels. An ultrasound confirms the presence of a roughly spherical, well-demarcated 2 cm nodule in the right lobe of the thyroid and normal cervical lymph nodes.

Diagnosis

What Is the Differential Diagnosis for a Thyroid Mass?

Table 14.1

Diagnosis	Description	Characteristics
<i>Thyroglossal duct cyst</i>	Congenital persistence of thyroglossal duct	Well-defined, smooth neck mass located in the midline, above the cricoid cartilage; elevates with tongue protrusion (swallowing)
<i>Multinodular goiter</i>	Multiple nodules distributed throughout the thyroid, can be toxic or nontoxic	Usually benign, may arise from iodine deficiency in childhood
<i>Benign follicular nodule</i>	Solitary nodule of follicular origin, may be solid or cystic (<i>colloid nodule</i>)	Common in the general population; prevalence increases with age, women > men
<i>Toxic adenoma</i>	Solitary nodule overproducing thyroid hormone	Almost always benign, appears as a “hot nodule” on thyroid scintigraphy; causes hyperthyroidism
<i>Graves’ Disease</i>	Autoantibodies that stimulate TSH receptor causing hyperthyroidism, diffuse enlargement, and hypervascularity of the thyroid	Ophthalmopathy (lid retraction, exophthalmos, extraocular muscle restriction, optic neuropathy) is present in half of patients
<i>Hashimoto’s thyroiditis</i>	Chronic lymphocytic infiltration and autoimmune destruction of the thyroid; usually painless; thyroid may be shrunken and fibrotic at the end stage	Positive serum TPO antibodies; patient euthyroid in early stage, progressing to hypothyroid over years
<i>Postpartum thyroiditis</i>	Painless goiter, due to autoimmune thyroid disease following pregnancy	Patient initially hyperthyroid, followed by euthyroid state, and then hypothyroidism
<i>Subacute thyroiditis</i>	Painful, transient goiter; cause unknown, possibly viral	Typically preceded by URI; patient hyperthyroid, followed by hypothyroidism
<i>Suppurative thyroiditis</i>	Transient, painful goiter due to bacterial infection. Most commonly due to <i>Staph. aureus</i> or <i>Strep. pyogenes</i>	Often preceded by URI; patient euthyroid
<i>Riedel’s thyroiditis</i>	Painless, progressive, firm, or “woody” goiter; cause unknown, results in extensive fibrosis	Mainly affects women, may have positive thyroid antibodies; patient hypothyroid or euthyroid
<i>Thyroid cancer (papillary, medullary, follicular, anaplastic lymphoma, metastases)</i>	Typically, nonfunctional, painless thyroid nodules occurring more often in females and extremes of age	Patient usually euthyroid; prognosis varies widely from extremely indolent (papillary) to highly lethal (anaplastic)

TPO thyroid peroxidase, URI upper respiratory infection

What Is This Patient's Diagnosis?

With an isolated nodule in the thyroid gland and symptoms of local invasion (e.g., hoarse voice), there is concern for thyroid cancer. However, there is insufficient information to make the diagnosis. The above table demonstrates the differential diagnosis for a thyroid mass.

History and Physical

What Are the Common Symptoms of a Patient with a Thyroid Nodule?

Patients often appreciate a lump in the anterior neck. Some may complain of shortness of breath, sensation of neck tight-

ness, voice changes, and/or dysphagia. It is important to also assess for symptoms of hyperthyroidism or hypothyroidism (discussed below).

How Common Are Thyroid Nodules, and How Often Are They Cancerous?

Palpable thyroid nodules can be found in approximately 5% of the population, and sonographically detectable thyroid nodules can be found in about half of the adult population. The great majority (95%) of thyroid nodules are benign. Thyroid cancer affects 0.2% of adults in the United States. The incidence of thyroid cancer has increased by threefold over the past 40 years.

Describe the Different Types of Thyroid Cancer?

Table 14.2

Type	Description	% of thyroid cancer	Characteristics
<i>Papillary adenocarcinoma</i>	Arises from follicular cells; presents as single nodule, often with internal calcifications, usually in early adulthood	~80%	<i>Slow growing</i> , excellent prognosis with overall survival rates ~95%; propensity to spread to regional lymph nodes; diagnosis established by characteristic nuclear features found on FNA
<i>Follicular adenocarcinoma</i>	Arises from follicular cells; occurs later in life than papillary; forms soft, rubbery, encapsulated tumors	10–20%	Good prognosis with overall survival rates ~85%; propensity to <i>spread hematogenously</i> to distant sites (most common is bone); <i>cannot be diagnosed on FNA</i> or frozen section; diagnosis rests on demonstration of capsular and/or vascular invasion on permanent section after thyroid lobectomy
<i>Hurthle cell carcinoma</i>	Subtype of follicular carcinoma; composed of Hurthle cells: large eosinophilic epithelial cells	5%	Similar to follicular carcinoma but with slightly worse prognosis (overall survival ~75%); most do not take up RAI
<i>Medullary carcinoma</i>	Arises from C (parafollicular) cells, secretes calcitonin; hard, solid, tumors containing amyloid	5–7%	Overall survival ~75%; commonly spreads to regional lymph nodes; miliary liver metastases also common; underlying germ line mutation exists in 25% of cases; associated with MEN-2A/B
<i>Anaplastic carcinoma</i>	Extremely aggressive cancer, likely dedifferentiated papillary or follicular thyroid cancer	1–2%	Median survival 6 months; uniformly lethal
<i>Thyroid lymphoma</i>	Typically, B-cell non-Hodgkin lymphoma	<5%	Usually develops in the setting of Hashimoto's thyroiditis
<i>Metastases to the thyroid</i>	Metastases from distant primary malignancy	<1%	Primary malignancy usually arises from the kidney, breast, lung, or skin (melanoma)

FNA fine-needle aspiration, RAI radioactive iodine

Watch Out

Although papillary thyroid carcinoma is known to *first* spread to the lymphatic system, the prognosis is based on the presence of local invasion.

What Are the Risk Factors for Thyroid Cancer?

Female gender, exposure to ionizing radiation, and family history of thyroid cancer. MEN-2A, MEN-2B, and familial medullary thyroid carcinoma account for 25% of medullary thyroid cancer cases and are all related to activating mutations in the RET proto-oncogene, a cell membrane tyrosine kinase. Papillary thyroid cancer is associated with Cowden syndrome, Gardner syndrome, and familial adenomatous polyposis. One-fifth of papillary thyroid cancers are due to RET/papillary thyroid carcinoma (PTC) rearrangements, which create a fusion gene comprised of PTC promoters and the RET tyrosine kinase. An estimated one-third or more are due to mutations in BRAF, a gene encoding a signal transduction protein kinase. Thyroid cancer occurs more frequently in women than men. However, nodules occurring in men and in children or the elderly are *more* likely to be malignant.

Watch Out

The developing thyroid gland is vulnerable to mutagenesis from low to moderate doses of ionizing radiation. The greatest increase in relative risk of thyroid cancer is associated with exposure before the age of 15. Today, the most common causes are childhood radiation exposure, treatment for lymphoma, and nuclear fallout.

What Are the Symptoms of Hyperthyroidism?

Nervousness, weight loss, heat intolerance, thirst, palpitations, pressured speech, and tremors. Women may have irregular or absent menses. Thyroid storm, a severe type of hyperthyroidism, causes high-grade fever, arrhythmia, bloating, diarrhea, and high-output cardiac failure and can be fatal.

Watch Out

The most common cause of death in patients with thyroid storm is high-output cardiac failure. It typically occurs in postoperative patients with undiagnosed Graves' disease. First-line therapy includes beta-blockers and propylthiouracil (PTU). Aspirin can precipitate thyroid storm.

What Are the Symptoms of Hypothyroidism?

Fatigue, weight gain, lethargy, hair changes, cold intolerance, constipation, difficulty with memory/cognition, impaired libido, and impaired fertility

How Should the Thyroid Be Examined?

To examine the thyroid, stand behind the patient, reach both hands around the patient's neck, and find the cricoid cartilage with the fingertips of both hands. The cricoid cartilage is the first complete cartilaginous ring below the thyroid cartilage (*Adam's apple*). The isthmus of the thyroid is located just a few millimeters below the cricoid. From there, move your fingers laterally to assess the thyroid lobes, checking for symmetry. Asymmetry is often the first clue to the presence of a thyroid nodule. Depress one side of the thyroid to rotate the contralateral lobe forward for a better feel. Do the same on the other side. Then ask the patient to swallow as it can help elevate the thyroid gland. The movement will often reveal a nodule that you did not appreciate before and may reveal an inferiorly located nodule that was previously hidden behind the clavicles. Lastly, run your fingertips with a crawling motion along the sternocleidomastoid muscle bilaterally, to examine for adenopathy.

What Is the Significance of the Mass Moving Up and Down with Swallowing?

The ligament of Berry attaches the thyroid gland to the trachea, causing it to move cranially when a patient swallows. A mass that moves with swallowing is more likely to originate within the thyroid gland as opposed to some other part of the anatomy (lymph nodes, for instance). In rare circumstances, an aggressive thyroid cancer will become fixed due to local invasion of surrounding structures. This is a worrisome sign.

Watch Out

Ectopic thyroid tissue in the lateral position of the neck is a well-differentiated thyroid cancer that has metastasized to cervical lymph nodes, until proven otherwise.

What Is the Appearance of a Patient with Severe or Long-Standing Hyperthyroidism?

Flushed face, warm skin, tremor, weight loss with possible muscle wasting, tachycardia, widened pulse pressure, and hyperactive reflexes

What Is the Appearance of a Patient with Severe or Long-Standing Hypothyroidism?

Periorbital swelling with puffy face and extremities, fine hair, loss of the outer aspects of the eyebrows, waxy or clammy skin, and weight gain

Pathophysiology

What Is the Function of the Thyroid Gland?

The thyroid contains follicular cells and parafollicular C cells. Follicular cells of the thyroid produce, store, and secrete the thyroid hormones thyroxine (T4) and triiodothyronine (T3). Synthesis of T4 and T3 requires iodide, which the thyroid takes up and stores. T4 is a precursor to T3 and T3 is considered 10x more potent. The thyroid normally produces 20% of circulating T3; the rest is converted from T4 in peripheral tissues. These remain protein bound in the circulation, and only the free fraction is active. The parafollicular C cells of the thyroid secrete calcitonin.

Watch Out

Most patients with thyroid carcinoma are euthyroid.

What Is Thyroglobulin?

Thyroglobulin (Tg) is a glycoprotein housed within thyroid follicles that is a storage form/precursor of T4 and T3. Serum thyroglobulin levels correlate positively with the amount of thyroid tissue, thyroid injury/inflammation, and the TSH level. Thus, serum Tg can be used as a tumor marker during surveillance after initial treatment of papillary and follicular thyroid cancer but only if a *total* thyroidectomy has been performed. Anti-Tg autoantibodies are present in about 20% of thyroid cancer patients and can interfere with Tg testing.

What Are the Actions of Thyroid Hormones?

In general, T4 and T3 regulate basal metabolic rate, growth and development, and sensitivity to catecholamines with effects on many organ systems.

Watch Out

Metastatic medullary carcinoma frequently causes diarrhea and flushing, thought to be due to the high *calcitonin* level.

What Is the Embryologic Origin of the Thyroid?

The primitive thyroid gland arises from the medial pharynx, part of the embryologic endoderm. This tissue descends along the thyroglossal duct into the neck and ultimately gives rise to thyroid follicles and colloid. The rostral-most aspect of the thyroglossal duct is the foramen cecum. Parafollicular C cells, which produce calcitonin, arise from the fourth pharyngeal pouch and migrate from the neural crest into the thyroid gland.

Watch Out

Ectopic thyroid tissue may be found anywhere along the thyroglossal duct as well as in the anterior mediastinum. Additionally, the thyroglossal duct may not completely obliterate, leaving behind thyroglossal duct cysts.

Why Isn't Fine-Needle Aspiration (FNA) Able to Diagnose Follicular Thyroid Carcinoma?

The determination of whether a follicular neoplasm is malignant is a histologic one, not a cytologic one (this differs from papillary cancer). In other words, it rests on whether the proliferation of follicles breaches the capsule and *invades* it. There are no distinguishing cellular features that mark it as malignant. Thus, fine FNA (which only aspirates cells) is not able to determine malignancy since it cannot assess for capsular invasion.

What Is Considered a Well-Differentiated Thyroid Cancer?

Tumors arising from follicular cells are categorized as well differentiated. This category includes papillary, follicular, and Hurthle cell carcinomas.

Watch Out

Thyroid cancer is considered the most common endocrine malignancy in the United States.

What Are Psammoma Bodies?

Microscopic finding of round, laminar collections of calcified tissue. It is seen in papillary thyroid cancer but also found in several malignant and benign lesions.

Watch Out

The cancers associated with psammoma bodies can be remembered by **PSaMMoma**: papillary carcinoma of the thyroid, serous cystadenocarcinoma of the ovary, meningioma, and mesothelioma.

Workup**What Laboratory Tests Are Recommended for a Thyroid Mass?**

The first test is a TSH level. This is the most sensitive measure of thyroid dysfunction and the only test indicated for screening or in the absence of symptoms of hyper- or hypothyroidism. T4 and T3 testing may be indicated if the TSH is abnormal.

What Are the Appropriate Imaging Studies for a Thyroid Nodule?

Bedside neck ultrasound performed by the surgeon is ideal and increasingly applied nationally. Ultrasound can detect nodules and lymphadenopathy, characterize masses as solid or cystic, and guide FNA. Hypoechoic nodules and those with irregular margins or microcalcifications are more likely to be malignant. Patients with clinical or sonographic evidence of locally advanced thyroid cancer that may extend

into the aerodigestive tract or substernal region should undergo further cross-sectional imaging with CT or MRI.

Is Routine Use of Nuclear Imaging Useful for an Isolated Thyroid Nodule?

Thyroid scintigraphy, performed with I^{123} , is rarely used today. Although iodine-avid (hyperfunctional or “hot”) nodules are virtually all benign, “cold” nodules (with low or no uptake, meaning they are nonfunctional) are only malignant in about 5% of cases. As such, whether a nodule is hot or cold is not that discriminating and has largely been replaced by FNA. The rare situation where scintigraphy is useful is in the setting where repeat FNA is indeterminate for malignancy. Rather than proceeding to open surgery, some advocate scintigraphy as it may obviate the need for biopsy if the nodule is hot.

What Nodules Should Undergo FNA?

Thyroid nodules greater than 1 cm in size, nodules with ultrasound characteristics suggestive of malignancy (e.g., internal microcalcifications), or those with a history of growth. Suspicious cervical lymph nodes should also undergo FNA during the same encounter. Nodules less than 1 cm, purely cystic nodules, and those with clearly benign sonographic features as determined by an experienced practitioner do not warrant FNA.

What Is the Bethesda Reporting System for FNAs of Thyroid Nodules?

Table 14.3

FNA result	Risk of malignancy (%)
<i>Benign</i>	0–3
<i>Atypia of undetermined significance or follicular lesion of undetermined significance (AUS/FLUS)</i>	5–15
<i>Suspicious for follicular neoplasm</i>	15–30
<i>Suspicious for malignancy</i>	60–75
<i>Malignant</i>	97–99
<i>Inadequate/nondiagnostic</i>	1–4

Management

What Is the Next Step in a Patient with an Inadequate/Nondiagnostic FNA?

An *inadequate* FNA is a technically failed biopsy which does not yield sufficient cells to establish a diagnosis. This must be distinguished from an *indeterminate* FNA, which is a technically successful biopsy with adequate cellular yield in which no definite diagnosis of a benign or malignant process can be made (corresponding to Bethesda categories AUS/FLUS and suspicious for follicular neoplasm). *Inadequate* biopsies should generally be repeated (■ Fig. 14.1).

What Is the Next Step for a Benign FNA Result?

Annual follow-up with ultrasonography. Nodules that enlarge and/or develop suspicious sonographic features warrant repeat FNA or surgical excision.

What Is the Next Step for an FNA Which Reports AUS or FLUS?

Management is controversial. The current accepted standard of care is to repeat FNA, since only 20% demonstrate FLUS a

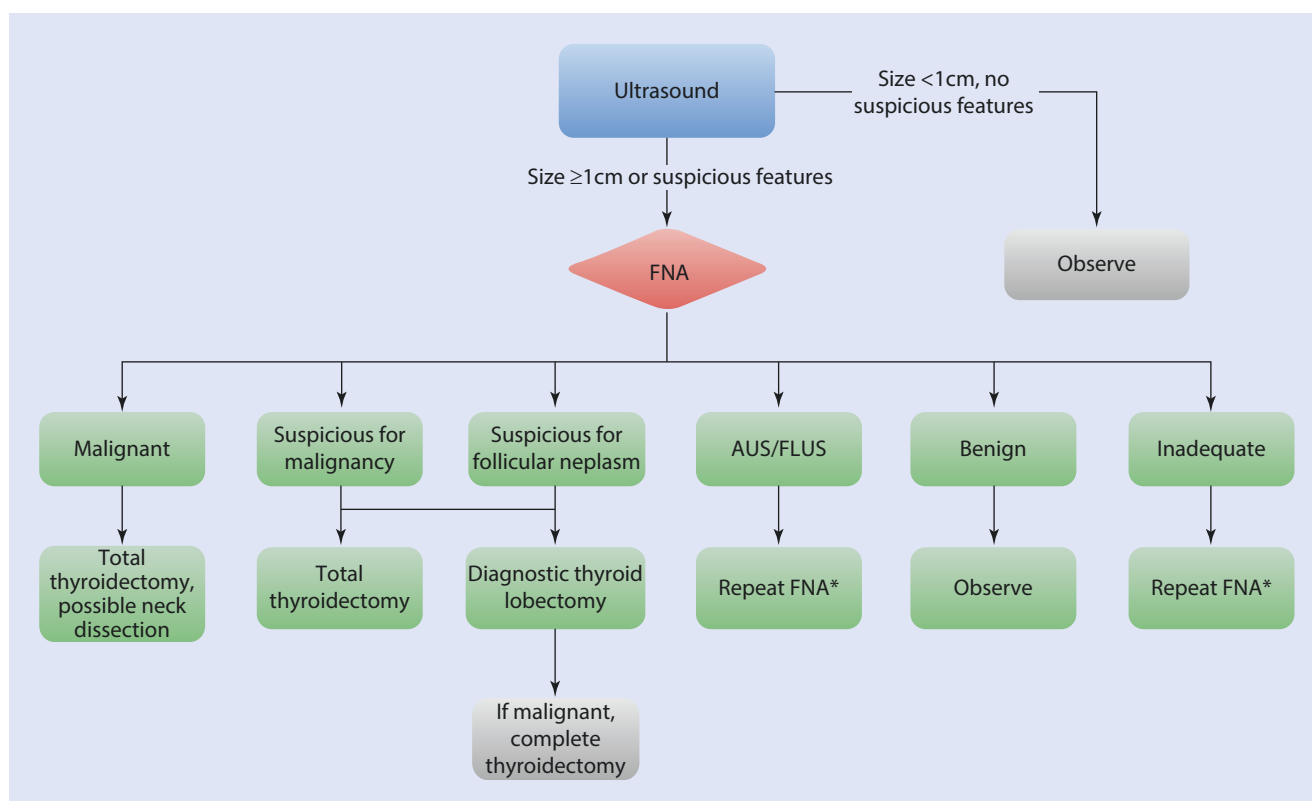
second time, with many nodules found to be benign on the second biopsy. Other options are molecular testing and diagnostic thyroid lobectomy.

What Is the Next Step for an FNA Result of Suspected Follicular Neoplasm?

Perform a thyroid lobectomy (hemithyroidectomy). There are several reasons for performing a lobectomy instead of a simple biopsy: (a) the thyroid gland is extremely vascular, and a biopsy would carry a higher risk of hemorrhage, (b) tumor cells may be spilled with a simple biopsy, and (c) removing a lobe of the thyroid does not adversely affect thyroid function. Approximately 25% of these lesions are ultimately found to be malignant. Follicular thyroid carcinoma is indistinguishable from follicular adenoma on FNA and can only be diagnosed on permanent surgical histopathology. Frozen section is generally not helpful for these lesions (see below).

What Is the Next Step if the Thyroid Lobectomy Reveals Follicular Cancer?

Patients found to have follicular carcinoma on lobectomy are typically offered a completion thyroidectomy at a later date. However, if the follicular thyroid cancer is less than 4 cm in size and does not have any high-risk features, lobectomy alone can be considered sufficient.



■ Fig. 14.1 Diagnostic algorithm for nonfunctioning solitary thyroid nodule found on examination or imaging

What Are the Advantages of Total Thyroidectomy in Thyroid Cancer Versus Lobectomy?

Removing the remainder of the thyroid allows for removal of any missed contralateral foci of thyroid cancer (present in up to 70% of cases). It also allows for using a radioactive iodine scan to detect/treat recurrence or metastases (otherwise the remaining thyroid lobe concentrates all the radioiodine). Finally, total thyroidectomy allows the use of serum thyroglobulin as a marker for recurrence.

What Thyroid Malignancy Is Amenable to Thyroid Lobectomy Alone? When Is Total Thyroidectomy Appropriate?

Small (<1 cm), unifocal, papillary thyroid carcinomas have such a favorable prognosis and low recurrence rates that total thyroidectomy is of little or no value. Hemithyroidectomy and total thyroidectomy are both considered appropriate for follicular and papillary thyroid cancers between 1 and 4 cm in size. Total thyroidectomy should be performed when tumors are larger than 4 cm, if extra-thyroidal extension is present, or if there is spread of disease to lymph nodes or distant sites.

Is It Ever Appropriate to Proceed Directly to Total Thyroidectomy Without Performing a Lobectomy First?

Surgeons will proceed directly to total thyroidectomy when the FNA returns suspected follicular neoplasm in the following scenarios: bilateral nodules, index nodule >4 cm (higher rate of malignancy), preexisting hypothyroidism, family history of thyroid cancer, or history of exposure to ionizing radiation (the latter two increase the risk of multicentric cancer).

What Is the Management of Anaplastic Thyroid Cancer?

Given the rarity and heterogeneity of presentation, therapy is not standardized. Initial surgical resection or debulking may be considered if preoperative imaging suggests feasibility. If not, chemotherapy and external beam radiation may be performed as first-line therapy, possibly followed by surgery in responsive cases. Treatment is generally palliative (given its aggressive nature) and may include early tracheostomy for airway protection.

Watch Out

The most common complication following thyroid surgery is hypocalcemia.

When Should Central Lymph Node Dissection Be Done? Lateral Neck Dissection?

For medullary and some papillary cancers. All patients with medullary thyroid carcinoma should undergo initial central neck dissection. The indications for central neck dissection in papillary thyroid carcinoma are controversial and discussed below. Lateral neck dissection (modified radical neck dissection) is generally performed when palpable or sonographically abnormal lymph nodes are found in the lateral compartment (jugular chain, deep to the sternocleidomastoid muscle). Follicular cancer spreads hematogenously so there is no role for lymph node dissection.

What Is the Role of Intraoperative Frozen Section Pathology?

Frozen section is generally not useful in the diagnosis of follicular thyroid lesions, and its use should therefore be highly selective. Frozen section may be used to confirm the presence of thyroid cancer within the lymph nodes.

Which Thyroid Cancers Concentrate Radioactive Iodine?

Most papillary thyroid cancers (70%) and follicular thyroid cancers (80%) concentrate radioactive iodine. This has important implications in the use of postoperative radioactive iodine ablation. Only a minority of Hurthle cell carcinomas (5%) concentrate iodine. Medullary thyroid cancers do not.

What Are the Important Elements of Postoperative Management of Thyroid Cancer?

Radioactive Iodine Ablation

Radioactive iodine (RAI) ablation with I^{131} may improve survival and reduce recurrences in a follicular thyroid carcinoma and a subset of high-risk papillary thyroid carcinomas.

Suppressive Thyroxine Therapy

TSH stimulates growth of target tissues. Thus, all thyroid cancers should undergo suppression of TSH with exogenous levothyroxine following surgery.

Follow-Up

Baseline measurement of thyroglobulin and anti-thyroglobulin antibodies should be measured twice annually and then annually when stable. After total thyroidectomy, thyro-

globulin (made in the follicle) should become undetectable. Detectable levels should arouse suspicion of recurrence in follicular and papillary thyroid cancers. Neck ultrasound should also be performed annually. Medullary thyroid carcinomas should be followed with serum calcitonin.

Watch Out

Tg antibodies can spuriously decrease serum Tg levels, leading to falsely negative test results. In the follow-up of thyroid cancer patients, Tg antibody levels and TSH should always be measured in conjunction with Tg, so that the Tg value can be interpreted in the appropriate context.

If You Suspect Recurrence, What Study Do You Perform?

If serum Tg levels increase on postoperative monitoring and there is concern for cancer recurrence, patients should first undergo neck ultrasound with a full lymph node survey by an experienced practitioner. This often demonstrates a target lesion that is amenable to FNA. Foci of thyroid cancer outside the neck may be detected by diagnostic I¹³¹ radionuclide scan or thin cut (non-contrast) chest CT.

Does External Beam Radiation Play a Role in Thyroid Cancer?

Yes, but it is only used in <5% of cases. External beam radiation is used for locally invasive tumors following incomplete resection (positive margins) or for palliation of bony metastases.

What Nonoperative Management Is Available for Thyroid Nodules?

Radioactive ablation with I¹³¹ can treat hyperfunctioning nodules, reducing tumor size and rendering patients euthyroid in 75% of cases. For nonfunctioning thyroid nodules, which are the great majority, the alternative is observation.

Complications

What Are the Major Structures That Can Be Injured During Thyroidectomy?

The recurrent laryngeal nerve, the external branch of superior laryngeal nerve, and the parathyroid glands. The recurrent laryngeal nerve, a branch off the vagus nerve, innervates all of the muscles of the larynx except the cricothyroid muscle. It also provides sensory innervation to the larynx below the vocal cords. Damage to the recurrent laryngeal nerve on

one side results in a paralyzed vocal cord in a median or paramedian position. This manifests as hoarseness and sometimes aspiration. The rate of permanent unilateral recurrent laryngeal nerve injury during thyroidectomy should be less than 2% in expert hands. The external branch of the superior laryngeal nerve permits speaking or singing in a high pitch. This nerve may be injured in up to 25% of cases but is usually asymptomatic unless the patient is a singer or voice professional. Permanent hypoparathyroidism usually results from devascularization of the parathyroids and should occur in less than 2% of cases. It is treated with calcium and calcitriol supplementation.

What Should Always Be Assessed Preoperatively in Patients Undergoing Thyroid Surgery that Have Had Previous Neck Surgery?

Indirect or direct laryngoscope to identify bilaterally functioning recurrent laryngeal nerves. Bilateral recurrent laryngeal nerve injury causes airway obstruction and may necessitate urgent tracheostomy, and so if a unilateral injury exists, this should be discussed with the patient prior to surgery.

What Is the Next Step if a Postoperative Patient Develops Stridor in the Recovery Room and the Neck Wound Appears to Be Tense?

Emergent bedside decompression of the hematoma – cut the sutures and open the wound. This usually relieves the airway obstruction immediately. The patient should then return to the operating room for evacuation of the hematoma, irrigation, and careful hemostasis.

Key Areas Where You Can Get in Trouble

Incomplete Family History in Patient with Thyroid Mass

Family history should not be overlooked. As mentioned above, 25% of patients with medullary thyroid cancer have an underlying germ line mutation: MEN-2A, MEN-2B, or familial medullary thyroid cancer. If medullary thyroid carcinoma is diagnosed on FNA, the immediate next steps are to review the family history and check 24-hour urine catecholamines and metanephrines to exclude pheochromocytoma. Even if there is no family history of endocrine disease, the patient may carry a de novo germ line mutation. Taking a patient to surgery for medullary thyroid carcinoma without first excluding pheochromocytoma biochemically is a potentially lethal error, as induction of anesthesia may trigger sud-

den release of catecholamines, resulting in stroke, acute myocardial infarction, or heart failure. Discovery of medullary thyroid cancer mandates genetic screening of the patient for RET mutations and, if positive, first-degree relatives. Children with known MEN-2A, MEN-2B, or familial medullary thyroid cancer should undergo prophylactic thyroidectomy; the recommended age for intervention varies by genotype. MEN-2B mutations are associated with the most aggressive medullary thyroid cancers, and known carriers should undergo thyroidectomy during the first year of life (B is Bad-er).

Obtaining CT with Iodinated IV Contrast in Patients with Thyroid Cancer

Prior to radionuclide imaging and ablation, patients are depleted of iodine by maintaining a low iodine diet for several weeks. This, combined with an elevated TSH (achieved by either thyroid hormone withdrawal or injection of recombinant human TSH), optimizes RAI uptake by thyroid cells. Iodinated contrast carries a large load of iodine and may suppress RAI uptake for up to 1 month.

Missing Postoperative Hypocalcemia

Postoperative hypoparathyroidism must be promptly recognized and treated in order to avoid hypocalcemic emergencies and near emergencies. Oral calcium supplementation is the preferred method of treatment. Because of the delayed action of oral calcium, an anticipatory rather than reactive protocol of managing postoperative hypoparathyroidism, aided by PTH measurement, is most effective.

Areas of Controversy

Overdiagnosis of Thyroid Cancer

The rising incidence of thyroid cancer is largely attributable to rising use of neck ultrasound, leading to increased detection. However, there is real concern that there is ongoing “overdiagnosis” of thyroid cancer – that we are now detecting cancers that otherwise would have been clinically insignificant throughout a patient’s lifetime. Accordingly, the US Preventative Task Force in 2017 started recommending against routine screening in asymptomatic adults.

Role of Prophylactic Central Neck Dissection (CND) for Papillary Thyroid Cancer

Reoperation for lymphadenectomy is difficult, and pathology reveals central lymph node involvement in 40–60% of

patients with papillary thyroid cancer with clinically negative nodes. Some surgeons advocate prophylactic central lymphadenectomy, citing the following benefits: improved staging, lower postoperative thyroglobulin levels, and a reduced need for reoperation. The effect of prophylactic CND on overall survival is unclear at this time. CND theoretically increases the risk of injury to the recurrent laryngeal nerve and the parathyroid glands; however, recent studies have shown no increase in the permanent complication rate within expert centers rate.

Summary of Essentials

History and Physical

- Thyroid nodules are common; thyroid cancer is relatively rare
- Risk factors for thyroid cancer are ionizing radiation exposure and family history of thyroid cancer
- Hyperthyroidism: nervousness, fatigue, weight loss, thirst, palpitations
- Hypothyroidism: fatigue, weight gain, constipation, impaired cognition/libido

Diagnosis

- The most important initial test is TSH
- Thyroid nodules should be evaluated with ultrasound. If TSH is elevated, get a radioactive iodine scan
- Iodine-avid, “hot” nodules have low risk of malignancy
- Thyroid nodules >1 cm, suspicious ultrasound findings, or increasing in size should undergo FNA

Pathophysiology

- The thyroid gland is comprised mostly of follicular cells that produce thyroid hormones T4 and T3 from thyroglobulin. There is a small population of parafollicular C cells that secrete calcitonin
- Papillary and follicular thyroid cancers arise from follicular cells; they are considered “well differentiated” and a majority take up iodine
- Medullary thyroid cancer arises from parafollicular C cells

Management

- FNA is the most important part of the initial workup of the solitary thyroid nodule
- Inadequate: repeat FNA
- Benign: observe
- AUS/FLUS: repeat FNA

- Suspicious for follicular neoplasm: diagnostic thyroid lobectomy
- Suspicious for malignancy: consider thyroid lobectomy versus total thyroidectomy
- Malignant: consider thyroid lobectomy, total thyroidectomy, and/or neck dissection

Watch Out

- Twenty-five percent of patients with medullary thyroid carcinoma have an underlying germ line mutation.
- Pheochromocytoma must be excluded biochemically prior to surgery in all patients with an FNA diagnosis of medullary thyroid carcinoma
- “Ectopic thyroid tissue” in the lateral neck usually metastasizes to cervical lymph nodes.
- Numbness and tingling in the lips and fingers after total thyroidectomy usually represent hypoparathyroidism and should be promptly treated with oral calcium
- Postoperative neck swelling accompanied by stridor is a hematoma compressing the airway. This is a surgical emergency requiring bedside decompression

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Question Set: Endocrine

Questions

1. A 35-year-old female presents with bone pain, abdominal pain, and depressed mood. Her laboratory examination is significant for calcium of 11.3 mg/dL (normal 8.5–10.2 mg/dL) and parathyroid hormone (PTH) of 109 pg/ml (10–55 pg/mL). Localization of the enlarged gland or glands is best achieved by:
- (A) Preoperative MRI
 - (B) Preoperative ultrasound
 - (C) Preoperative sestamibi scan
 - (D) Preoperative fine-needle aspirate (FNA)
 - (E) Intraoperative exploration of all four glands
2. A 38-year-old female arrives for her yearly physical. She has no complaints but was incidentally found to have laboratory markers suggestive of primary hyperparathyroidism. Subsequent workup reveals involvement of all four parathyroid glands. She remains asymptomatic. What is the best recommendation for management of this patient?
- (A) Observation
 - (B) Surgical removal of all four glands
 - (C) Surgical removal of 3.5 glands
 - (D) Biochemical monitoring of serum calcium and serum creatinine annually
 - (E) Cinacalcet
3. A 45-year-old man has had hazy vision for the past month, particularly when he is driving at night. He also endorses small rubberlike nodules on the skin of his trunk, back, arms, and legs that are not painful and do not itch. After seeing his ophthalmologist, he is diagnosed with bilateral cataracts and is scheduled to receive elective cataract surgery. During induction of anesthesia, following intubation, the patient's pressure increases from 110/70 to 200/90 mmHg. PaCO₂ is normal as is his pH. His temperature is 38.4 °F. An esmolol drip is immediately instituted, after which BP increases to 220/90 mmHg and an electrocardiogram shows T-wave inversion. What is the most likely underlying etiology?
- (A) Intra-abdominal tumor
 - (B) Malignant hyperthermia
 - (C) Thyrotoxicosis
 - (D) Inadequate anesthetic agent
 - (E) Undiagnosed pituitary tumor
4. A 12-year-old boy presents to the doctor for a lump in his neck. He is healthy with no previous medical problems. On physical examination, he has a well-defined anterior neck mass, located in the midline and above the cricoid cartilage. The mother states that she has noted the lesion since he was about 2 years old. It does not bother him. On physical examination, the mass elevates with swallowing and is non-tender. He has no cervical adenopathy and no other complaints. The neck mass is described as a hypoechoic mass on ultrasonography. A subsequent thyroid scintigram is performed and confirms the thyroid gland is in its correct anatomic position. Which of the following would be recommended next for this mass?
- (A) Fine-needle aspirate (FNA)
 - (B) Proceed to surgical excision
 - (C) Reassurance and observation
 - (D) Thyroid stimulating hormone (TSH) and free T4
 - (E) CT scan

5. In addition to elevated plasma free metanephrine, a change in what other serum marker can help support the diagnosis of pheochromocytoma?
- (A) Plasma chromogranin-A
 - (B) Plasma superoxide dismutase
 - (C) Malondialdehyde
 - (D) CA 19-9
 - (E) 5-Hydroxyindoleacetic acid (HIAA)
6. An elderly nursing home patient has been bedridden for several months due to a series of debilitating strokes. Past medical history is significant for hypertension, controlled with a diuretic, and Paget's disease. Recently, the patient has been complaining of vague abdominal pain, constipation, and depressed mood. On physical examination, the patient is alert and oriented. Abdominal examination is unremarkable. Which of the following electrolyte abnormalities would most likely explain her symptoms?
- (A) Hyponatremia
 - (B) Hypernatremia
 - (C) Hyperphosphatemia
 - (D) Hypocalcemia
 - (E) Hypercalcemia
7. Which of the following is most consistent with an aldosterone-secreting adrenal adenoma?
- (A) Hyperglycemia, hirsutism, and abdominal striae
 - (B) Hypertension and hyperkalemia
 - (C) Hypertension in a patient taking potassium supplements
 - (D) Elevated plasma metanephrine and hypertension
 - (E) Increased vanillylmandelic acid excretion and hypertension
8. A 35-year-old patient presents for a follow-up visit for an elevated serum calcium level of 12.8 mg/dL and an elevated parathyroid hormone (PTH). He is a thin man without a significant past medical history. He reports that for the past 2 weeks, he has been experiencing loose stools, polydipsia, and polyuria. On physical exam he was found to have large erythematous erosions with blisters over the lower abdomen. Which tumor would best explain the patient's symptoms and rash?
- (A) Insulinoma
 - (B) Prolactinoma
 - (C) VIPoma
 - (D) Glucagonoma
 - (E) Adrenal adenoma
9. A 32-year-old female patient arrives for follow-up for new-onset hypertension. She was started on hydrochlorothiazide 6 months ago. During her visit, she was found to have a blood pressure of 152/98 mmHg. She also complains of recent episodes where she experiences sudden palpitations, chest pain, diaphoresis, headache, and anxiety. Her laboratory exam demonstrates a calcium of 13.2 mg/dl (normal 8.5–10.2 mg/dl), parathyroid hormone (PTH) of 102 pg/ml (10–55 pg/ml), and an elevated plasma metanephrine. Which of the following would be an important additional component in the workup?
- (A) Fasting blood glucose
 - (B) Prolactin level
 - (C) MRI of the sella turcica
 - (D) Serum calcitonin
 - (E) Serum gastrin level
10. A 55-year-old otherwise healthy patient undergoes a non-contrast CT abdomen to evaluate for possible kidney stones and is incidentally noted to have a 8 cm mass in the left adrenal gland. The mass has irregular borders and high attenuation,

suggesting a lipid-poor lesion, and appears to be adherent to the kidney. How should this patient be managed?

- (A) Observation with repeat CT scan in 3 months
- (B) Open adrenalectomy
- (C) Laparoscopic adrenalectomy
- (D) Radiation therapy
- (E) Percutaneous biopsy

11. A 50-year-old female has been recently diagnosed with primary hyperparathyroidism. She comes in to her doctor complaining of increased bone pain in her legs. She is found to have elevated serum calcium, alkaline phosphate, and parathyroid hormone (PTH). Her doctor decides to order plain films of her lower extremities. The radiographs show very thin bones with a stress fracture and bowing of both femur bones. She also has characteristic cysts with a moth-eaten appearance. What is the most likely diagnosis?
- (A) Osteoporosis
 - (B) Osteopetrosis
 - (C) Osteomalacia
 - (D) Osteitis fibrosa cystica
 - (E) Paget's disease of the bone
12. A 60-year-old man is found to have a 3 cm right adrenal mass on CT scan which was obtained a month earlier following a motor vehicle accident. He is asymptomatic, and does not report a history of hypertension or diabetes. What is the most appropriate next step in management?
- (A) Repeat CT scan in 6 months
 - (B) Percutaneous needle biopsy
 - (C) Biochemical workup for hormone excess
 - (D) Laparoscopic adrenalectomy
 - (E) No further follow-up is necessary
13. A 42-year-old man with a family history of endocrine tumors is diagnosed with MEN-2A after presenting with uncontrolled hypertension and subsequent genetic workup. He was found to have a right adrenal pheochromocytoma and asymptomatic hyperparathyroidism. What is the recommended surgical management for this patient?
- (A) Parathyroid surgery first, followed by adrenalectomy
 - (B) Adrenalectomy first, followed by parathyroid surgery
 - (C) Medical conditioning for 2 weeks prior to adrenalectomy, followed by parathyroid surgery
 - (D) Medical conditioning for 2 weeks prior to simultaneous parathyroid surgery and adrenalectomy
 - (E) Medical conditioning for 2 weeks followed by adrenalectomy only
14. A 39-year-old man is recovering from bilateral adrenalectomy for bilateral functional adrenal adenomas. On his second postoperative day, he begins to complain of nausea, vomiting, weakness, blurry vision, and mild abdominal pain. His temperature is 38.5 °C, and blood pressure is 90/68 mmHg. His electrocardiogram shows sinus tachycardia. His laboratory examination from that morning showed:
- Sodium: 134 mEq/L (137–145 mEq/L)
Potassium: 5.8 mEq/L (3.6–5.0 mEq/L)
Calcium: 7.4 mg/dL (8.9–10.4 mg/dL)
BUN: 12 mg/dL (7–21 mg/dL)
Creatinine: 1.2 mg/dL (0.5–1.4 mg/dL)
Glucose: 70 mg/dL (65–110 mg/dL)
Albumin: 2.4 g/dL (3.5–4.8 g/dL)
WBC $10.5 \times 10^3/\mu\text{L}$ ($4.1\text{--}10.9 \times 10^3/\mu\text{L}$)

Which of the following can best explain this patient's current presentation?

- (A) Volume depletion
- (B) Sepsis
- (C) Hypocalcemia
- (D) Low cortisol
- (E) Loss of catecholamine production

15. A 56-year-old woman is recovering after undergoing total thyroidectomy for papillary carcinoma. Her temperature is 37.9 °C, blood pressure is 120/80 mmHg, and pulse is 90/min. During her postoperative examination by the intern, the patient complains of numbness and tingling around her mouth and in her hands and feet. What could have been done postoperatively to anticipate and potentially remedy these symptoms?
- (A) Check magnesium
 - (B) Check parathyroid hormone (PTH)
 - (C) Check potassium
 - (D) Check thyroid stimulating hormone (TSH) and free T4
 - (E) Carotid ultrasound
16. A 42-year-old man presents with new-onset hypertension and elevated hemoglobin (19 mg/dL) and hematocrit (58%) level on subsequent laboratory examination. A CT scan demonstrates bilateral adrenal masses suspicious for pheochromocytoma. His elevated hemoglobin and hematocrit are believed to be secondary to a paraneoplastic syndrome. What other tumor is classically associated with this same paraneoplastic syndrome?
- (A) Glioblastoma multiforme
 - (B) Hemangioblastoma
 - (C) Colorectal cancer
 - (D) Wilms' tumor
 - (E) Osteosarcoma
17. Which of the following is true regarding paragangliomas (extra-adrenal pheochromocytomas)?
- (A) The most common location is within the kidney.
 - (B) There is a decreased association with familial syndromes (e.g., MEN-2, Von Hippel-Lindau) compared to pheochromocytomas.
 - (C) They are less likely to be malignant compared to pheochromocytomas.
 - (D) Functional imaging (MIBG) is particularly useful to diagnose metastatic disease, particularly when CT/MRI are negative.
 - (E) They are likely to produce similar amounts of epinephrine compared to adrenal pheochromocytomas.
18. A malignant pheochromocytoma is diagnosed by:
- (A) Pathologic identification of high mitotic rate, cellular atypia, and capsular invasion
 - (B) Positive MIBG scan
 - (C) Presence of metastasis at sites normally devoid of chromaffin tissue
 - (D) Biomolecular markers
 - (E) The presence of intractable hypertension
19. A 45-year-old female presents with a 2 cm painless mass in her right anterior neck that has been present for 3 months and slowly enlarging. On physical exam, the mass feels firm and moves up and down with swallowing. She denies weight loss, weight gain, heat intolerance, or anxiety. A serum thyroid stimulating hormone (TSH) level is normal. The most important step in the workup is:
- (A) CT scan of the neck
 - (B) MRI of the neck
 - (C) Fine-needle aspiration (FNA)
 - (D) Open biopsy
 - (E) Nuclear scan

20. Three hours after total thyroidectomy for thyroid cancer, the patient complains of difficulty breathing. On physical examination, the patient has stridor and appears to be in moderate respiratory distress. Examination of the wound demonstrates tense swelling. The next step in the management is:
- (A) Immediately reopen wound at the bedside
 - (B) Intubation
 - (C) Emergent return to the operating room for wound exploration
 - (D) Check oxygen saturation
 - (E) Send arterial blood gas
21. During the course of a total thyroidectomy in a 40-year-old female, the surgeon divides the superior thyroid artery and vein in one large ligature. After dividing the vascular pedicle, the surgeon notices that it appears that a nerve was transected. The surgeon postoperatively should warn the patient that she will most likely have:
- (A) Permanent hoarseness
 - (B) A droop in the corner of her mouth
 - (C) Difficulty swallowing
 - (D) Trouble hitting high notes when singing
 - (E) A need for a permanent tracheostomy
22. A 45-year-old female presents to her physician complaining of abdominal pain. She has a history of recurrent kidney stones and was recently discharged from the hospital after undergoing ureteroscopic laser lithotripsy. Her laboratory examination is significant for calcium of 13.6 mg/dL (normal 8.5–10.2 mg/dL) and parathyroid hormone (PTH) of 112 pg/mL (10–55 pg/mL). She is scheduled for operative management of her underlying condition. At surgery, all four parathyroid glands are identified. Only one appears to be abnormally enlarged and is removed. Confirmation of curative resection is best achieved via:
- (A) Intraoperative ultrasound
 - (B) Intraoperative frozen section
 - (C) Intraoperative PTH levels
 - (D) Immediate postoperative serum calcium level
 - (E) Postoperative sestamibi scan
23. A 27-year-old woman has 3 months of intermittent spells of severe headache, heart palpitations, and sweating. A pregnancy test at her primary care doctor's office is positive. Further workup reveals that her plasma metanephrine level is 220 pg/mL (normal 12–60 pg/mL). What is the next step in establishing the diagnosis?
- (A) CT abdomen
 - (B) Repeat plasma metanephrine level after the patient has delivered
 - (C) MRI abdomen
 - (D) I¹³¹-MIBG scan
 - (E) Reassure patient that symptoms are related to pregnancy
24. Preoperative medical optimization for a patient with a pheochromocytoma routinely includes:
- (A) Octreotide drip for 24 hours before surgery
 - (B) Control of hypertension with beta-blockade as first-line agent
 - (C) Control of hypertension with alpha-blockade as first-line agent
 - (D) Metyrosine
 - (E) Diuretics for blood pressure management

Answers

✓ 1. Answer C

Sestamibi scanning involves using a radioisotope, technetium-99 m, which is taken up by cells with high mitochondrial activity. It is more accurate for single adenomas than for four-gland hyperplasia. Sestamibi scanning and to a lesser extent ultrasound are the most frequently used imaging tests to localize the involved gland(s) in primary hyperparathyroidism (B). Localizing studies are generally not indicated in secondary or tertiary hyperparathyroidism, since multiple-gland hyperplasia is the expected underlying pathology. Preoperative FNA is not helpful in the workup of primary hyperparathyroidism (D). In about 85% of patients, imaging will localize the abnormal parathyroid gland, and a great majority will have a single parathyroid adenoma. If localizing scans are negative, yet the diagnosis of primary hyperparathyroidism is clearly established, surgery is still performed at which time intraoperative exploration of all four glands is performed (E).

✓ 2. Answer C

With the increasing use of routine laboratory testing, most patients with primary hyperparathyroidism are currently discovered incidentally in asymptomatic patients. Although the patients may be asymptomatic, long-standing hyperparathyroidism can lead to kidney injury and osteoporosis. Evidence of such should be sought out via bone mineral density testing as well as calculation of creatinine clearance. For patients with asymptomatic hyperparathyroidism diagnosed through laboratory screening, a 2013 consensus statement recommended the following indications for surgery:

1. Serum calcium level of 1.0 mg/dL greater than the upper limit of normal
2. Creatinine clearance reduced to <60 mL/min
3. Elevated 24-hour urine calcium >400 mg/day AND increased risk for calcium stone formation on biochemical stone risk analysis
4. Presence of asymptomatic nephrolithiasis or nephrocalcinosis seen on imaging
5. Bone mineral density with T-score less than -2.5 at any site
6. Evidence of vertebral fracture
7. Age <50
8. Patients that do not desire or cannot undergo routine surveillance

The patient described meets the age criterion for surgical intervention. The surgical treatment of primary hyperparathyroidism due to four-gland hyperplasia is to remove 3.5 glands. An acceptable alternative is to remove all four glands and to reimplant half of a gland within the muscles of the forearm. That way if the patient develops recurrent hyperparathyroidism, additional parathyroid tissue can be removed from the forearm under local anesthesia as opposed to re-operative neck surgery with the attendant risk of cranial nerve injury. Removal of all four glands is not recommended as it will render the patient permanently hypocalcemic with a lifelong need for calcium supplementation (B). Observation would not be appropriate for patients meeting criteria for surgery (A). Patients not selected for surgical therapy require biochemical monitoring of serum calcium and serum creatinine annually (D). Bone mineral density should be measured every 1–2 years. Cinacalcet, a calcimimetic, is mainly used to treat secondary hyperparathyroidism (seen in patients with renal failure) (E). It may be considered to reduce the serum calcium in patients who are not candidates for surgery.

✓ 3. Answer A

A sudden rise in blood pressure after anesthetic induction raises concern for an undiagnosed pheochromocytoma, malignant hyperthermia, and thyrotoxicosis (thyroid storm). For each of these situations, cessation of anesthesia is recommended. There are several clues that point to pheochromocytoma as the cause. The administration of beta-blockers without alpha-blockade first leads to worsening hypertension due to unopposed alpha-mediated vasoconstriction as in the case above. Pheochromocytoma is associated with neurofibromatosis-1 which may present with skin neuro-

fibromas (rubberlike discolored skin lesions) and cataracts (hazy vision). Malignant hyperthermia presents with muscle rigidity (most often the masseter), a rapid increase in core body temperature, a rise in end tidal CO_2 , arrhythmia, and a mixed metabolic and respiratory acidosis at anesthetic induction (B). Treatment is immediate cessation of surgery and dantrolene. Thyrotoxicosis presents in a similar fashion to malignant hyperthermia (fever, hypertension, tachycardia); however, it is not associated with muscle rigidity or rising end tidal CO_2 (C). The associated hypertension and tachycardia respond to the administration of beta-blockade. It is due to a hypermetabolic state caused by excess thyroid hormone. Inadequate anesthetic agents may lead to hypertension and tachycardia but would not lead to high fevers (D). An undiagnosed pituitary tumor resulting in excess ACTH production can cause hypertension, but this will be accompanied with symptoms consistent with Cushing's disease (e.g., truncal obesity, abdominal striae, muscle wasting, hirsutism) (E).

- ✓ 4. Answer B
This patient has a thyroglossal duct cyst, which is the most common midline congenital malformation of the neck. Though present at birth, these do not often appear until age two as baby fat recedes. During embryological development, the thyroid originates at the base of the tongue and travels down the thyroglossal duct to the anterior neck, where it normally involutes. However, if a persistent duct remains, it may undergo cystic dilation later in life and present as a well-defined anterior neck mass, located midline and above the cricoid cartilage. Unlike a brachial cleft cyst, this elevates with tongue protrusion or swallowing. Ectopic thyroid gland may be associated with thyroglossal duct cysts, so it's necessary to confirm the thyroid gland is in its correct anatomic location prior to surgical intervention. The definitive management involves thyroglossal duct cyst excision with removal of the hyoid bone (Sistrunk procedure). Reassurance and observation are inappropriate as thyroglossal duct cysts have a high rate of recurrent infections and a small risk of progressing to malignancy (C). FNA is appropriate for a thyroid nodule, but not for suspected thyroglossal duct cyst (A). He does not have symptoms suggestive of hyper- or hypothyroidism, so a thyroid panel would not be indicated (D). CT scan is unnecessary for the diagnosis and additionally should not be performed in such a young patient secondary to significant radiation exposure (E).
- ✓ 5. Answer A
Plasma free metanephrine is highly sensitive for pheochromocytoma but is more prone to false-positive results. Plasma chromogranin-A is released from neuroendocrine cells and is elevated in the majority of patients with pheochromocytoma. It is nonspecific (i.e., it is elevated in other neuroendocrine tumors) but can help confirm the diagnosis. Superoxide dismutase and malondialdehyde are both markers for oxidative stress, and neither has been shown to be associated with pheochromocytoma (B–C). CA 19–9 may be elevated in some patients with pancreatic cancer (D). Increased level of HIAA would be expected in a patient with carcinoid syndrome (E).
- ✓ 6. Answer E
Hypercalcemia can cause abdominal pain, constipation, mental status changes, and depressed mood (stones, bones, moans and groans) (A–D). Prolonged immobilization is a known cause of hypercalcemia and is seen in adolescents and in other patients with increased bone turnover such as Paget's disease. This can also present in trauma patients with whole-body casting after polytrauma. Certain diuretics (thiazide) also cause hypercalcemia by increasing renal calcium resorption.
- ✓ 7. Answer C
Patients with hyperaldosteronism have hypertension and hypokalemia – not hyperkalemia (B). A patient on a potassium supplement is suggestive of hypokalemia. Aldosterone acts on the kidney to increase sodium reabsorption, and potassium is excreted to balance the positively charged sodium ions. Hyperglycemia, hirsutism, and abdominal

striae are more consistent with Cushing's syndrome (A). Elevated plasma metanephrine, hypertension, and increased vanillylmandelic acid excretion are all consistent with pheochromocytoma (D–E).

- ✓ 8. Answer D
Elevated serum calcium combined with elevated PTH is consistent with primary hyperparathyroidism. Rarely, it can be associated with MEN-1 which includes parathyroid, pituitary, and pancreatic pathology (3Ps). Pancreatic tumors include gastrinoma, insulinoma, VIPoma, and glucagonoma. Glucagonoma should be suspected in a patient with the 4 Ds: diabetes, dermatitis, deep vein thrombosis, and depression. The classic rash (dermatitis) is described as annular, erythematous erosions with blisters over the lower abdomen and termed *necrolytic migratory erythema*. The patient's symptoms of polyuria and polydipsia are highly suggestive of diabetes mellitus. Insulinoma is characterized by hypoglycemia, headache, visual changes, confusion, weakness, and diaphoresis (A). Prolactinomas are excess prolactin-producing anterior pituitary tumors that may result in amenorrhea, galactorrhea, decreased libido, and gynecomastia (B). A VIPoma (C) (also called WDHA syndrome: watery diarrhea, hypokalemia, achlorhydria) presents with profuse diarrhea, but will not have any skin manifestations of the disease. An adrenal adenoma is oftentimes benign, nonfunctional, and incidentally found on imaging (incidentalomas) (E).
- ✓ 9. Answer D
Severe hypertension in a young patient should raise suspicion for surgically correctable causes such as aldosteronoma, Cushing's disease, coarctation of the aorta, fibromuscular dysplasia of the renal arteries, and pheochromocytoma. Her symptoms, combined with an elevated plasma metanephrine level, make pheochromocytoma the most likely cause. The addition of labs consistent with primary hyperparathyroidism (elevated calcium and PTH) suggests she has MEN-2A which is characterized by primary hyperparathyroidism, pheochromocytoma, and medullary thyroid cancer. Calcitonin is a reliable tumor marker for medullary thyroid cancer and should always be ordered to rule out this very aggressive cancer in this patient population. Fasting blood glucose (A) (insulinoma), prolactin levels (prolactinoma) (B), MRI of the sella turcica (C) (pituitary adenoma), and serum gastrin level (E) (gastrinoma) are all associated with MEN-1.
- ✓ 10. Answer B
This patient was incidentally found to have an adrenal mass. Guidelines for surgical resection include tumors >6 cm, features on CT suspicious for malignancy (high attenuation, irregular borders, inhomogeneous), and those that are hormonally active. Most adrenal carcinomas are hormonally active. Thus, the patient described has several indications for adrenalectomy. Open adrenalectomy is preferred when malignancy is suspected, as this allows for a wider resection with en bloc resection if adjacent structures are involved and eliminates the possibility of seeding the port sites that may occur with laparoscopic adrenalectomy (C). Laparoscopic adrenalectomy is preferred for benign lesions. Radiation therapy is not the mainstay of treatment for adrenal cortical carcinoma (D). Percutaneous biopsy is not recommended as there are no histologic features that diagnose adrenal cortical carcinoma and a biopsy may risk seeding the biopsy tract (E).
- ✓ 11. Answer D
Osteitis fibrosa cystica is a skeletal disorder that results from a surplus of parathyroid hormone. Patients experience increased bone pain, bone fractures, and skeletal deformities with bowing of the bones. Radiographs show thin bones, fractures, and cysts with a moth-eaten appearance. Osteoporosis usually occurs in elderly patients and is characterized by decreased bone density with normal mineralization (A). It does not have any associated cyst-like features. In contrast, osteopetrosis is known as "stone-

bone” and occurs when the bone becomes increasingly dense. It would not have any cysts seen on plain films (B). Paget’s disease results from overactive osteoclasts and osteoblasts leading to excessive bone turnover and is characterized by tibial bowing, kyphosis, increased cranial diameter, and deafness (E). Patients with Paget’s disease and osteoporosis have normal serum calcium, while patients with osteomalacia would be expected to have decreased serum calcium (C).

✓ 12. Answer C

The first step in the evaluation of an incidentally discovered adrenal mass is to perform a biochemical workup to determine if the tumor is functional or nonfunctional (E). In practice, it is common to order a single battery of tests: serum aldosterone, plasma renin activity, and a 24-hour urine collection to simultaneously measure catecholamines, metanephrines, and cortisol. Given that this patient is normotensive, the suspicion for pheochromocytoma and hyperaldosteronism is low. In addition, adrenal masses <6 cm are unlikely to be malignant. If the 3 cm mass is found to be a hormonally active adrenal adenoma, then laparoscopic adrenalectomy would be recommended (D). If biochemical testing reveals a nonfunctioning mass, this small lesion may be observed with interval CT scanning (A). Percutaneous needle biopsy cannot readily distinguish between benign and malignant primary adrenal tumors and is generally discouraged as it can possibly potentiate a hypertensive crisis in hormonally active tumors. The only clinical utility in biopsying the adrenal gland is in the case of suspected metastatic disease as it may change management.

✓ 13. Answer C

Patients with MEN-2A can develop pheochromocytoma, hyperparathyroidism, and medullary thyroid cancer. The definitive management for pheochromocytoma consists of medical conditioning with alpha-blockade and sometimes beta-blockade for at least 2 weeks, followed by an adrenalectomy (B). This should be performed first (A, D–E) because a pheochromocytoma can increase the risk of complications during the surgical management of other endocrine tumors. Although he is asymptomatic with respect to his hyperparathyroidism, parathyroid surgery is generally recommended for most patients with inherited forms, as it tends to be more aggressive and presents at a much younger age. Age less than 50 is an indication for parathyroid surgery for sporadic forms as well, as the patient is more likely to suffer one of the sequelae of hyperparathyroidism.

✓ 14. Answer D

If a patient that has undergone bilateral adrenalectomy presents postoperatively with severe hypotension and hypoglycemia, suspect Addisonian crisis (acute adrenal insufficiency). This patient should receive immediate fluid resuscitation (normal saline) and intravenous corticosteroids. This is considered to be a life-threatening condition caused by insufficient levels of cortisol, which is responsible for maintaining blood pressure and glucose homeostasis. Patients will present with nausea, vomiting, weakness, blurry vision, fever and mild abdominal pain. Laboratory exam would be expected to show low cortisol, hypoglycemia, hyperkalemia, and mild hyponatremia. Plasma ACTH levels will be low, and a Cortrosyn (synthetic ACTH) stimulation test will demonstrate a low cortisol response. Acute adrenal insufficiency does not respond to vasopressors. Additionally, it can mimic sepsis. However, sepsis is unlikely to present with this patient’s lab abnormalities (B). Patients that have had major surgery should always be monitored for signs of internal hemorrhaging. Although his serum calcium is shown to be low, this should be corrected for hypoalbuminemia (C). His corrected serum calcium is 8.7 mg/dL, is within the normal range, and would not explain the hypotension. Although he may be volume depleted, this would not cause hypoglycemia or hyperkalemia (A). Loss of catecholamine production may accompany Addisonian crisis and is also seen after removing a pheochromocytoma (E). It is associated with hypotension and hypoglycemia; however, it will not cause hyperkalemia and hyponatremia.

✓ 15. Answer B

The patient most likely has hypocalcemia. Temporary hypoparathyroidism occurs in up to 30% of patients after total thyroidectomy and generally lasts a few weeks. It is thought to be related to temporary ischemia to the adjacent parathyroid glands. Patients will complain of numbness and tingling in their hands and feet, as well as around the mouth. These patients should be managed with prompt oral calcium supplementation. Oral calcitriol may be added to increase calcium absorption from the gut. Some centers routinely check the postoperative PTH level for the purposes of anticipating hypocalcemia. Left untreated, hypocalcemic symptoms may progress to muscle twitching (including Chvostek's sign) and ultimately tetany, which is an emergency. IV calcium (gluconate or chloride) may be given in these circumstances, but its use can generally be avoided when patients are carefully monitored postoperatively. Symptoms of hypomagnesemia are indistinguishable from hypocalcemia; however, low magnesium levels are not associated with thyroidectomy (A). Disturbances in potassium and thyroid hormone would not cause the symptoms described (C–D). Carotid ultrasound would be indicated if the patient developed symptoms of a stroke or transient ischemic attack (one-sided arm and leg weakness/numbness) (E).

✓ 16. Answer B

This patient most likely has an ectopic production of erythropoietin (EPO) leading to high levels of hemoglobin and hematocrit. This paraneoplastic syndrome, termed *polycythemia vera*, is classically associated with pheochromocytoma, renal cell carcinoma, hepatocellular carcinoma, and hemangioblastoma (A, D–E).

✓ 17. Answer D

Paragangliomas arise from extra-adrenal chromaffin tissue, with the most common location being at the organ of Zuckerkandl which is near the origin of the inferior mesenteric artery or bifurcation of the iliac arteries (A). They are essentially identical on a cellular level to intra-adrenal pheochromocytomas. However, they are more likely to have a hereditary basis (30–50% of cases) and to be malignant (15–35%) (B–C). The diagnosis is made by biochemical analysis followed by imaging localization. It is particularly important to consider a whole-body functional scan due to the higher propensity for multifocal and metastatic disease. Extra-adrenal pheochromocytomas produce little to no epinephrine as they do not have the enzyme required that catalyzes norepinephrine to epinephrine (PNMT) (E).

✓ 18. Answer C

There is currently no way to establish the diagnosis of malignancy in pheochromocytoma based on histopathologic evaluation (A). However, there are tumor characteristics that are associated with higher risk (e.g., larger size, extra-adrenal location, certain genetic mutations, and a high tumor proliferative index). Malignancy is determined by the development of metastatic disease, defined by a recurrence in an area that normally does not have any chromaffin tissue (lymph nodes or a distant site such as the liver or lungs). MIBG scanning can be useful to identify metastatic disease, but positivity of the primary tumor on MIBG does not determine whether it is malignant (B). Biomolecular markers can differentiate a functional tumor from nonfunctional but is unable to rule out malignancy (D). Similarly, intractable hypertension is not a characteristic of malignancy (E).

✓ 19. Answer C

The most important step in the diagnostic workup of a thyroid nodule is to obtain a tissue sample. This is best obtained via FNA under ultrasound guidance. Thyroid nodules greater than 1 cm in size, nodules with ultrasound characteristics suggestive of malignancy (e.g., internal microcalcifications), or those with a history of growth should undergo ultrasound-guided FNA. CT or MRI would be appropriate for patients found to

have clinical or sonographic evidence of locally advanced thyroid cancer that may extend into the aerodigestive tract or substernal region (A–B). Open biopsy, done by removing an entire thyroid lobe, should be done next if FNA results are suggestive of cancer (D). Nuclear scanning has a very limited role in the preoperative setting (E). It is more beneficial in the postoperative setting to look for recurrent or metastatic malignancy.

✓ 20. Answer A

Don't forget the ABCs. This patient has a compromised airway and is in moderate respiratory distress. Normally, the first step to ensure an airway is via endotracheal intubation (B). However, a neck hematoma is in a closed space that leads to compression of the airway that may render safe intubation difficult or impossible. As such, the first step is to immediately open the neck wound at the bedside to decompress the hematoma. This will typically relieve the airway obstruction. The patient can then be transported emergently to the operating room for intubation, wound exploration, adequate hemostasis, and subsequent wound closure (C). Although thyroidectomy is considered a safe procedure, one well-known complication is airway obstruction following bleeding and hematoma formation which occurs within the first 24 hours after thyroidectomy. Checking oxygen saturation or waiting for labs is never appropriate for a patient with a compromised airway (D–E).

✓ 21. Answer D

The superior laryngeal nerve lies adjacent to the superior thyroid artery and is thus at high risk of being injured during mobilization of the thyroid, particularly the superior pole. The external branch of the superior laryngeal nerve permits singing in a high pitch. This nerve may be injured in up to 25% of cases but is usually asymptomatic unless the patient is a singer or voice professional. Damage to the recurrent laryngeal nerve on one side results in a paralyzed vocal cord in a median or paramedian position. This manifests as hoarseness and sometimes aspiration (A). The rate of permanent unilateral recurrent laryngeal nerve injury during thyroidectomy should be less than 2% in expert hands. If both recurrent laryngeal nerves were injured during a total thyroidectomy, then both vocal cords could be paralyzed, and this may lead to a compromised airway which may necessitate a permanent tracheostomy (E). Therefore, it is imperative to perform a flexible laryngoscopy to visualize the vocal cords in a patient with previous neck surgery that is scheduled for parathyroid or thyroid surgery. A droop in the corner of the mouth results from injury to the marginal mandibular branch of the facial nerve (B). Swallowing is controlled by multiple nerves including the glossopharyngeal, vagus, and/or hypoglossal nerves (C).

✓ 22. Answer C

The surgical treatment of hyperparathyroidism depends on whether the pathology is a single adenoma (most common; remove single gland), more than one adenoma (remove abnormal ones), or four-gland hyperplasia (common in MEN-1 and 2A; remove 3.5 glands). Distinguishing these entities is not always obvious. Because of the short half-life of PTH (about 4 minutes), intraoperative rapid PTH testing aids in determining the completeness of parathyroid resection. The most commonly used protocol involves drawing PTH levels at the time of gland excision and again 10-minute post-excision. A fall of >50% in the PTH level is associated with a 98% long-term cure rate. Given the small size of the parathyroid glands, it is generally not recommended to biopsy all of them for frozen section, as such a biopsy may render all the glands ischemic (B). Transient hypocalcemia is expected following parathyroidectomy so postoperative serum calcium level is not indicative of cure (D). Oral calcium supplementation can help alleviate minor symptoms. Intraoperative ultrasound is sometimes used when the abnormally enlarged gland cannot be found (A). Sestamibi scan may be used if recurrent or persistent hyperparathyroidism develops but is not routinely used for confirmation of successful surgery (E).

✓ 23. Answer C

This patient presents with the rare but classic presentation of pheochromocytoma during pregnancy. The preferred imaging modality in pregnancy is an MRI, due to the risks of exposing the fetus to radiation with other types of imaging (A, D). In men and non-pregnant women, CT with contrast can be considered a first-line imaging study. Pheochromocytoma is usually hyperintense on T2-weighted images due to its high water content. Failing to work up and treat a potential pheochromocytoma in pregnancy exposes the fetus and mother to a very high risk of mortality during the pregnancy and delivery (B, E).

✓ 24. Answer C

Patients with pheochromocytoma are volume depleted due to intense alpha-mediated vasoconstriction. Hypertension is controlled with alpha-blockade (e.g., phenoxybenzamine) for 10–14 days before surgery. This allows for volume expansion, and the patient is encouraged to liberally intake salt and fluids. The dose is titrated until hypertensive episodes are controlled, often resulting in *mild orthostatic hypotension*. Beta-blockers can be used to decrease reflex tachycardia once appropriate alpha-blockade has been established (B). Initiating beta-blocker therapy prematurely can precipitate a hypertensive crisis due to unopposed alpha-adrenergic vasoconstriction. Octreotide is a somatostatin analogue that may have minimal efficacy in the palliation of symptoms from malignant pheochromocytoma, but it has no role in preparing a patient for surgery (A). Metyrosine inhibits catecholamine production and is a secondary agent for pheochromocytoma, though now rarely used (D). Diuresis would be contraindicated as these patients are volume depleted (E). In fact, some patients may need to be admitted preoperatively for continuous maintenance fluids prior to surgery.

Head and Neck

Vishad Nabili

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Progressively Hoarse Voice

Kevin A. Peng, Irene A. Kim, and Vishad Nabili

Case Study

A 62-year-old male presents with a 2-month history of a progressively hoarse voice. Initially, his voice was only slightly raspy, but over time, he has lost the ability to project his voice and is only able to speak in a loud whisper. He endorses blood-tinged sputum with coughing, which has occurred

approximately twice a week for the past month. His social history is remarkable for a 40-pack-year smoking history, and he continues to smoke 1 pack per day. On review of systems, he denies dyspnea, dysphagia, and odynophagia. On physical examination, his voice is breathy and

raspy. His oral cavity and oropharynx are remarkable only for caries, and his neck is supple, without lymphadenopathy. Flexible laryngoscopy performed in clinic reveals friable masses on both vocal cords, with a widely patent airway but with impaired mobility of the left vocal cord.

Diagnosis

What Is the Differential Diagnosis for Hoarseness?

Table 15.1

Diagnosis	History and physical
<i>Viral laryngitis</i>	Acute onset of fever, sore throat, cough, and/or other symptoms consistent with upper respiratory tract infection
<i>Vocal cord paralysis</i>	Breathy voice, most commonly idiopathic or iatrogenic (e.g., injury to recurrent laryngeal nerve during thyroid or thoracic surgery)
<i>Vocal cord nodules, polyps, cysts, or granulomas</i>	Unilateral or bilateral lesions usually resulting from trauma to the vocal cord (voice abuse, endotracheal intubation)
<i>Recurrent respiratory papillomatosis</i>	Benign, occasionally aggressive growths caused by HPV
<i>Spasmodic dysphonia, Parkinson's disease, or other neurological disorder</i>	Vocal tremors or an intermittently breathy or strained voice
<i>Laryngeal cancer</i>	Subacute to chronic onset of dysphonia, possibly with cervical lymphadenopathy (signifying cancer metastasis to regional lymph nodes); smoking is the single greatest risk factor

HPV human papillomavirus

Watch Out

Many lesions that cause hoarseness concomitantly narrow the airway. Be on the lookout and remember the ABCs: airway first, followed by breathing, circulation.

What Is the Most Likely Diagnosis in This Patient?

The patient's age, male gender, history of smoking, subacute onset, progression of symptoms, hemoptysis, and friable mass on vocal cords are all concerning for malignancy (most likely squamous cell carcinoma of the larynx). The absence of cervical lymphadenopathy does not rule out the possibility of laryngeal cancer.

History and Physical Examination

What Information Can the Nature of Hoarseness Provide?

Hoarseness, more strictly termed dysphonia, can be qualified specifically. In order to phonate (produce a sound), the vocal cords must move and oppose at the midline (adduction). To breathe, the vocal cords must open (abduction). A *breathy* voice is caused by incomplete closure, as seen with a unilateral vocal cord paralysis. *Aphonia*, the inability to create any vocal sound, is usually due to vocal cords that remain far abducted during attempted phonation. This can be due to mucosal swelling or irregularities precluding any vibration from occurring along the vocal cord. A *strained* voice usually implies a narrowing at the level of the vocal cords, as with a laryngeal mass such as papillomatosis or carcinoma. A *tremulous* voice may indicate a neurological disorder, such as spasmodic dysphonia or Parkinson's disease.

At What Point Should Hoarseness Warrant Consultation with an Otolaryngologist?

The most common cause of hoarseness is viral laryngitis and is self-limited usually resolving after 1–2 weeks. Any hoarseness persisting for longer than 2 weeks necessitates timely otolaryngologic referral.

Is History of Tobacco or Alcohol Use Important to Know?

Tobacco use, in both smoked and chewed forms, is the single greatest risk factor for squamous cell carcinoma of the upper aerodigestive tract. Alcohol use multiplies the risk of cancer in the presence of tobacco use.

What Is the Significance of Bloody Sputum?

The vast majority of noncancerous causes of hoarseness are not associated with bloody sputum. Hemoptysis or bloody oral secretions are a red flag for malignancy in the upper aerodigestive tract.

What Is the Most Common Type of Laryngeal Cancer?

The most common type of cancer found in the larynx, as well as in the entire upper aerodigestive tract, is *squamous cell carcinoma*. The pathogenesis is closely linked to tobacco use in any form.

Watch Out

The most common site of malignant lesions of the larynx is the glottis. However, the most common oral cavity cancer is on the tongue.

Pathophysiology

What Is the Innervation of the Larynx?

Table 15.2

Nerve	Branch	Sensory	Motor
Superior laryngeal nerve (external branch)	Vagus	None	Cricothyroid
Superior laryngeal nerve (internal branch)	Vagus	Supraglottis	None
Recurrent laryngeal nerve	Vagus	Glottis and subglottis	All intrinsic laryngeal muscles except cricothyroid

Why Is Tobacco Use a Risk Factor for the Development of Squamous Cell Carcinoma of the Head and Neck?

Chemicals contained in tobacco cause chronic inflammation of the mucous membranes of the upper aerodigestive tract. In turn, chronic inflammation and increased cell turnover lead to metaplasia and dysplasia. As the dysplasia becomes severe, it is termed carcinoma in situ. Invasion of these dysplastic cells past the basement membrane of the involved mucosa classifies a lesion as invasive squamous cell carcinoma.

What Are the Potential Consequences of Unrecognized Squamous Cell Carcinoma of the Upper Aerodigestive Tract?

Squamous cell carcinoma of the larynx, if diagnosed early, portends a favorable prognosis. However, other mucosal sites of the head and neck carry a graver prognosis, and if the diagnosis is made late in the course of disease, the cancer may lead to eventual mortality.

Do Laryngeal Papillomas Cause Cancer?

Laryngeal papilloma, also known as recurrent respiratory papillomatosis, is a condition caused by human papilloma-viruses (HPV) 6 and 11. Infection with the virus can lead to benign papillary tumors of the larynx, which present primarily with hoarseness. Adults tend to have more limited papillomas, while children develop multiple lesions. Though possible, papillomas rarely give rise to laryngeal carcinoma.

Workup

What Examination Should Be Performed to Evaluate the Vocal Cords?

The otolaryngologist will perform a laryngoscopy in the office setting (■ Fig. 15.1). This may be achieved with a mirror introduced via the mouth (mirror laryngoscopy) or, more commonly, with an endoscope passed through the nasal cavities (flexible fiber-optic laryngoscopy). Structural abnormalities, such as masses, ulcers, or mucosal irregularities, may be noted. Functionally, the otolaryngologist will be able to assess motion of the vocal cords, which are innervated by the recurrent laryngeal nerve. These maneuvers, grouped under *indirect laryngoscopy*, may be differentiated from *direct laryngoscopy*. Direct laryngoscopy is typically performed under general anesthesia. A metal *laryngoscope* is passed into the patient's mouth, and dedicated examination of the patient's oral cavity, pharynx, and larynx is performed. The otolaryngologist may perform biopsies of any suspicious lesions, which will be sent for histopathological analysis.

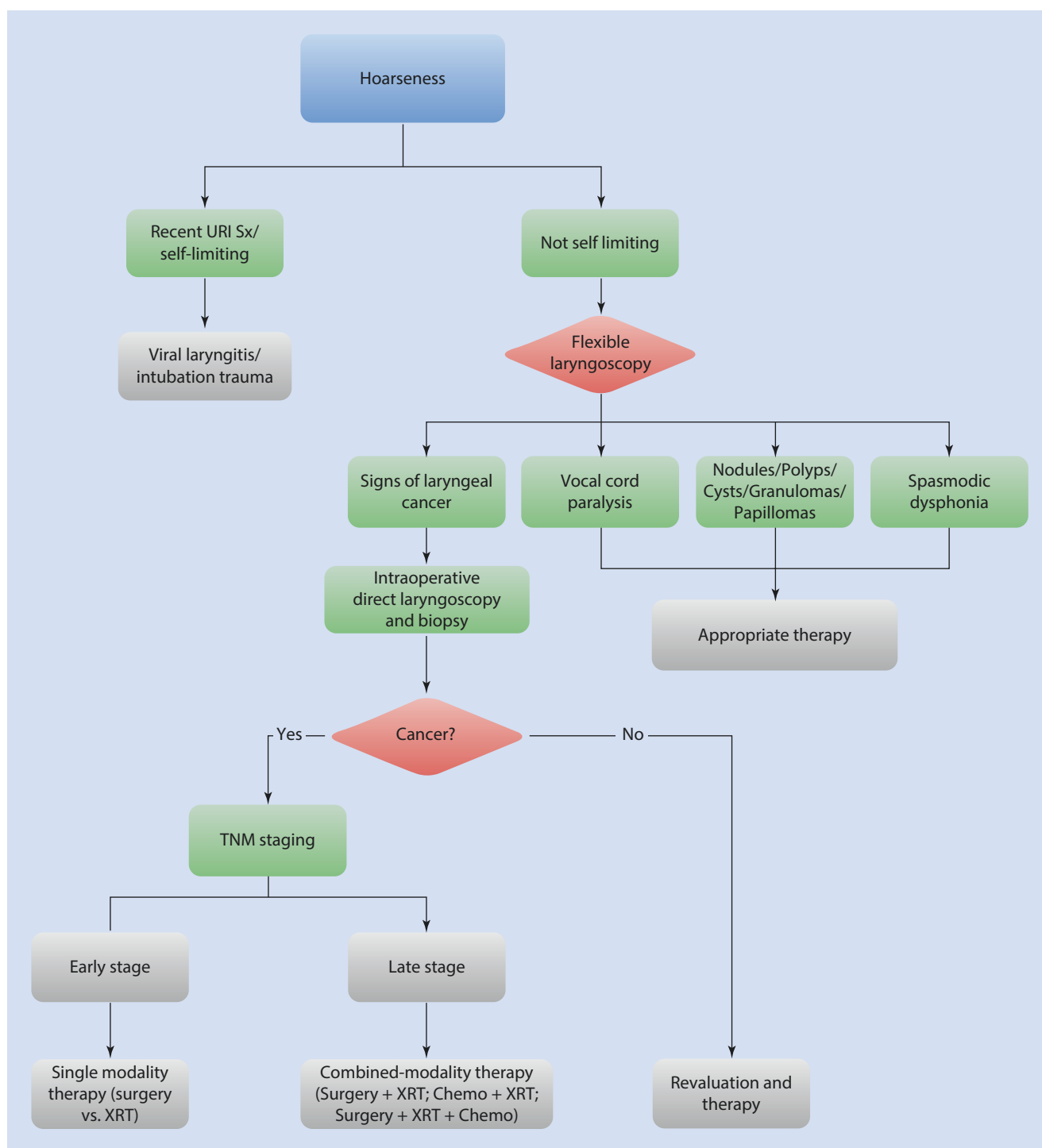


Fig. 15.1 Algorithm for diagnosis and management of hoarseness

If Laryngeal Cancer Is Suspected, What Additional Tests Are Warranted?

A *chest X-ray* is routinely performed to rule out a concurrent primary lung cancer or pulmonary metastases. This is important because a majority of laryngeal and lung cancers are attributed to smoking. In addition, the most common location for distant metastasis of head and neck squamous cell carcinoma is the lungs. *Computed tomography (CT)* of the

neck can reveal metastases to cervical lymph nodes, although CT is not routinely obtained for early-stage laryngeal cancer.

What Is the Staging for Laryngeal Cancer?

As with a majority of human cancer, laryngeal cancer is staged by the *tumor, node, metastases (TNM)* system established by the American Joint Committee on Cancer (AJCC). This takes

into account the location, size, and extent of the primary tumor, the presence and degree of metastasis to cervical lymph nodes, and the presence of distant metastases. The *TNM* staging is beyond the scope of what is required for students.

Management

What Treatments Are Available?

In *early-stage laryngeal cancer* (TNM stage I and II), single-modality therapy—either surgery or radiation—is usually effective in eradicating the disease (■ Table 15.3). In *late-stage head and neck cancer* (TNM stage III and IV), combined-modality therapy (surgery and radiation, chemotherapy and radiation, or a combination of all three) is often required to eradicate the disease. In patients with suspected or confirmed metastases to cervical lymph nodes, a *neck dissection* (*cervical lymphadenectomy*) may be required to remove the lymph nodes of the neck. This accomplishes two purposes: cancer-containing lymph nodes are removed as part of an oncologic resection, and the number of lymph nodes containing cancer may be counted to guide further management and dictate prognosis.

Watch Out

The primary goal in treating laryngeal cancer is to try to preserve the larynx.

What Variables Affect Prognosis for Laryngeal Cancer?

The TNM stage is the single most important prognostic indicator. The 5-year relative survival of stage I laryngeal cancer is 90%, while stage IV is approximately 45%.

Areas Where You Can Get in Trouble

Chronic Laryngitis as a Red Flag

“Laryngitis” is a term commonly used by primary care physicians to denote any laryngeal derangement causing hoarseness. The most common cause of dysphonia, or a hoarse voice, is a viral infection leading to edema of the vocal cords,

■ Table 15.3 Treatment options for early-stage laryngeal cancer

	Pros	Cons
Surgery	Performed in a single operation	May have increased vocal breathiness following surgery
Radiation	Excellent vocal outcome	Requires weeks of daily therapy

resulting in a raspy or breathy voice. This should resolve over the course of 1–2 weeks; persistent hoarseness beyond that time necessitates timely otolaryngologic referral.

Airway Compromise

The larynx is the narrowest segment of the human airway. An exophytic mass, such as a squamous cell carcinoma, can cause life-threatening airway obstruction. This may present in a chronic fashion, where a patient with known squamous cell carcinoma becomes increasingly short of breath, or it may present more acutely. In a patient with advanced laryngeal cancer, a tracheostomy may very likely be necessary prior to initiating any treatment.

Summary of Essentials

History and Physical Examination

- Duration, progression, and quality of hoarseness
- Tobacco use, including smoking as well as chewing tobacco
- Alcohol use

Etiology/Pathophysiology

- Chronic inflammation and increased cellular turnover from toxic insults, such as tobacco smoke, lead to dysplasia and invasive squamous cell carcinoma

Diagnosis

- Indirect laryngoscopy in the office, or direct laryngoscopy in the operating room setting, to visualize the larynx and to obtain biopsies
- Chest X-ray
- CT of the neck
- TNM staging

Management

- Early stage
 - Radiation
 - Surgical resection
- Late stage
 - Chemotherapy with radiation.
 - Surgery followed by radiation.
 - Tracheostomy may be necessary to secure airway.

Watch Out

- Hoarseness that persists >2 weeks merits immediate referral to an otolaryngologist.

Suggested Reading

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Hoffman HT, Porter K, Karnell LH, et al. Laryngeal cancer in the United States: changes in demographics, patterns of care, and survival. *Laryngoscope*. 2006;116(9 Pt 2 Suppl 111):1–13.

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Lump on the Neck Increasing in Size

Jon Mallen-St. Clair, Aaron J. Feinstein, and Vishad Nabili

Case Study

A 58-year-old man presents with a right-sided neck mass that has been increasing in size over the past 3 months. He denies fever, chills, or recent weight loss. He also denies sore throat, difficulty swallowing, changes in his voice, or difficulty breathing. Past

medical history is significant for hypertension and gastroesophageal reflux disease (GERD). Social history is significant for 20 pack-years of smoking. He averages two alcoholic drinks every day. Physical exam of the oral cavity/oropharynx including close

visualization of the tongue, tonsils, and floor of the mouth reveals no obvious lesions that are suspicious for malignancy. Examination of the neck reveals a 2 × 3-cm firm right-sided neck mass that is poorly mobile, non-erythematous, and not tender to palpation.

Diagnosis

What Is the Differential Diagnosis? (Apply the “KITTENS” Mnemonic)

Table 16.1

Condition	Comments
<i>K – congenital</i>	
Thyroglossal duct cyst	Midline mass, moves with tongue protrusion; may become infected; <i>most common</i> congenital neck anomaly
Branchial cleft cyst	Lateral to midline; at risk for infection
Dermoid cyst	Arises from entrapment of the epithelium during fetal midline closure
Laryngocele	Intermittent lateral neck swelling caused by herniation of a laryngeal diverticulum through the thyrohyoid membrane; may arise from chronic severe cough or sustained blowing into a musical instrument
Sebaceous cyst	Arises from obstruction of the sebaceous gland duct; may become infected
Lymphangioma	Lymphatic ducts that do not communicate with the internal jugular lymphatic system resulting in impaired drainage; also known as cystic hygroma
Thymic cyst	Only requires excision if causing compression of other structures; may occasionally be ectopic parathyroid tissue
<i>I – infectious/inflammatory</i>	
Lymphadenitis	Viral, bacterial, or fungal infection causing lymph node enlargement
Tuberculosis	Lymph nodes may be matted together and form draining sinus tract; also known as scrofula
Actinomycosis	Suppurative lymph nodes form sinuses with a bright-red color; pus contains sulfur granules
Deep neck abscess	Present with fever, pain, stiffness, odynophagia, purulent oral secretions; retropharyngeal infection may spread to the mediastinum
<i>T – toxin</i>	
Metals/drugs	Exposure to industrial fumes, nickel, cigarette smoke, and wood dust has been associated with head and neck cancers, which can metastasize to lymph nodes and present as a neck mass
<i>T – trauma</i>	
Hematoma	Contusion or vascular injury; may compromise airway, may require surgical exploration
Foreign body	Shrapnel or bullet
Aneurysm	Blunt or penetrating injury may cause pseudoaneurysm of the carotid artery
<i>E – endocrine</i>	
Thyroid hyperplasia	Graves' disease, goiter
Ectopic thyroid gland	May be found anywhere along the thyroglossal duct; beware of lateral ectopic thyroid tissue as this may be metastatic spread of malignancy

Table 16.1 (continued)

Condition	Comments
<i>N – neoplastic</i>	
Benign growths	Lipoma, neuroma, fibroma
Malignant growths	Thyroid carcinoma, lymphoma, salivary gland carcinoma, carotid body (paraganglioma)
Metastatic	Unknown primary, mucoepidermoid, adenoid cystic, lung, breast, kidney, GI
<i>S – systemic</i>	
Viral	Human immunodeficiency virus; increased susceptibility to infections
Kawasaki disease	Autoimmune disease associated with coronary artery abnormalities

Data from Stackler RJ, Shibuya TY, Golub JS, Pasha R. General Otolaryngology. In: Raza Pasha, Justin S. Golub, ed. Otolaryngology-head and neck surgery: clinical reference guide. 4th ed. San Diego: Plural Publishing. 2014: 275–278 and Eustermann VD. Tumors of the Oral Cavity and Pharynx. In: Bruce W. Jafek, Bruce W. Murrow, eds. ENT Secrets. 3rd ed. Philadelphia: Mosby Elsevier. 2005: 221–222

What Is the Most Likely Diagnosis for This Patient?

A neck mass in a patient over the age of 40 should be considered malignant until proven otherwise. The “rule of 80s” should be applied. A neck mass in an adult has an 80% chance of being neoplastic and 80% chance of being malignant. In contrast, >80% of pediatric neck masses are benign. History of alcohol and tobacco use also increases the risk of cancer. The progressive increase in size of the mass is also consistent with malignancy. The absence of “B” symptoms (fever, chills, weight loss) and the unilateral nature of the mass argue against lymphoma. Furthermore, there is no history of exposure to infection (tuberculosis, recent travel) which would suggest an infectious etiology. In addition, infectious neck masses are typically tender, with overlying erythema. The most likely diagnosis is a metastatic lymph node (most likely squamous cell) from an unknown primary. Further work-up is needed to confirm that the neck mass is a metastatic lymph node and, if so, to find the source of the primary tumor.

What Risk Factors Are Associated with Head and Neck Cancer in General?

Alcohol and tobacco in combination confer a greater risk. Also, male gender, age >40 years, poor dental hygiene, radiation exposure, and blacks (compared to whites).

What Risk Factors Are Associated with Specific Head and Neck Cancers?

Table 16.2

Risk factor	Type of cancer
HPV	Oropharyngeal cancer
EBV	Nasopharyngeal cancer, Burkitt's lymphoma
Chinese	Nasopharyngeal cancer
GERD	Laryngeal cancer
Plummer-Vinson syndrome ^a	Pharyngeal and upper esophageal cancer

HPV human papillomavirus, EBV Epstein-Barr virus, GERD gastroesophageal reflux disease

^aSymptoms include glossitis, cervical dysphagia, iron deficiency anemia, and esophageal webs

How Have the Demographics of Head and Neck Cancer Changed in the Last 10 Years?

The last decade has brought about a significant rise in oropharyngeal squamous cell carcinoma (SCC) primarily in white males from the ages of 40–55 years. These patients typically present with a neck mass as the initial presentation. There is

often limited exposure to alcohol and tobacco found on the historical interview. This demographic has been found to have SCC associated with HPV. HPV-associated oropharyngeal cancer is different from alcohol- and tobacco-associated SCC in many regards, and these patients often have an improved response to radiation therapy. Given the improved survival of patients with HPV-associated SCC, a new staging system has been developed and validated to reflect the improved survival of these patients. Currently efforts to de-intensify treatment for HPV-associated SCC so as to decrease treatment-related morbidity are at the forefront of clinical research.

What Symptoms Can Be Associated with Head and Neck Cancer, and What Are the Likely Sources?

■ Table 16.3

Symptom	Definition	Pathophysiology/possible malignant sources
Otalgia	Pain in the ear	Cranial nerves IX and X supply sensory innervation to both the tongue and floor of the mouth and also supply sensory innervation to the ear; pain can be referred to the ear from CN IX via Jacobson's nerve and CN X via Arnold's nerve; in addition, the lingual nerve (V3) supplies sensation to the tongue and floor of the mouth as well as the external auditory canal and tympanic membrane via the auriculotemporal nerve
Dysphagia	Difficulty in swallowing	Mass effect of tumor obstructing the path of food bolus (hypopharynx) vs. interference with swallowing mechanism (common in the pharynx/tongue/hypopharynx)
Odynophagia	Pain with swallowing	Tumor-related inflammation can cause pain
Dysphonia	Impairment in producing voice sounds	Lesion on vocal cords blocking efficient phonation or vocal cord paralysis from neural involvement
Dyspnea	Difficulty breathing	Upper airway obstruction
Trismus	Limited opening of the jaw	Tumor invasion into pterygoid muscles
Stridor	High-pitched sound resulting from a narrowed or obstructed airway	Upper airway obstruction
Hemoptysis	Expectoration of blood-stained sputum	Ulceration of tumor into the blood vessel in the upper airway vs. secondary pulmonary lesion

What Are the Key Aspects of the Head and Neck Exam in the Evaluation of a Solitary Neck Mass?

Though it is tempting to focus completely on examination of the neck, it is imperative that a full head and neck exam be performed. This should include careful inspection and palpation of the scalp, skin, parotids, ears, ear canals, nose, nasal cavity, oral cavity, and oropharynx. In particular, the base of the tongue and tonsillar fossa should be palpated for any evidence of firmness. Full characterization of the neck mass should be performed, with assessment of the size, location, mobility, consistency, fluctuance, overlying skin changes, and associated pain. A full cranial nerve exam should be performed to assess for deficits, which are often associated with advanced head and neck cancer.

What Premalignant Lesions Should Be Looked for on Physical Examination?

Look for leukoplakia (white patch or plaque) on the buccal mucosa or lower lip and for erythroplakia (red patch or lesion) on the floor of the mouth, tongue, or soft palate.

Etiology

What Is the Differential Diagnosis for Salivary Glands Tumors? What Is Their Malignant Potential?

The salivary glands include the parotid, submandibular, sublingual, and minor salivary glands. Masses in large salivary glands are more likely to be benign, while masses in smaller salivary glands are more likely to be malignant. However, the parotid glands (the largest salivary glands) are the most frequent site of malignant tumor. Refer to ■ Table 16.4 for the common salivary gland tumors.

Table 16.4

Tumor	Comment
Pleomorphic adenomas (mixed tumor)	Most common benign salivary gland tumor
Papillary cystadenoma (Warthin's tumor)	Second most common benign salivary gland tumor; smokers, can be bilateral
Mucoepidermoid carcinoma	Most common malignant salivary gland tumor
Adenoid cystic carcinoma	Second most common malignant salivary gland tumor

What Is Virchow's Node? Why Is It Concerning?

Virchow's node is an enlarged left supraclavicular node. It occurs on the left as this is where the cisterna chyli (dilated lymph sac at the end of the thoracic duct) empties into the subclavian vein. Virchow's node is suggestive of metastatic lung or gastrointestinal malignancy.

What Are the Most Common Sites of Head and Neck Cancer?

The oral cavity (tongue most common), larynx, and pharynx represent 44%, 31%, and 25% of head and neck cancers, respectively.

What Is Meant by the Term "Primary Tumor"? What Is Meant by "Unknown Primary"?

A primary tumor refers to the original anatomic site of a tumor growth. An unknown primary tumor refers to a situation where a metastatic tumor such as a cancerous lymph node is discovered and the site of the original cancer is not evident.

What "Primary Tumors" Arise in the Neck?

Primary tumors of the neck include lymphoma, thyroid neoplasms, salivary neoplasms, schwannomas, paragangliomas, and lipomas, among others.

What Does a Newly Discovered Malignant Neck Mass Most Likely Represent?

Malignant neck masses represent spread of cancer via the lymphatic system (metastatic lymph node) until proven otherwise. In these cases, the primary site of cancer is unknown

and thus represents an "unknown primary." The primary site is most frequently in the upper aerodigestive tract and must be found in order to appropriately treat the cancer. The unknown primary can also more rarely represent a distant metastasis from breast, lung, or renal cancer. There is a less than a 15% chance that a malignancy that is found in the neck represents a primary neck tumor.

What Types of Abscess Are in the Differential of a Neck Mass?

Table 16.5

Type of abscess	History and physical	Treatment
Peritonsillar	Older children (>10 years), fever, odynophagia, ear pain, muffled voice, trismus, uvula deviation; does not typically cause airway obstruction	Needle aspiration and drain through the tonsillar bed
Retropharyngeal	Younger children (<10 years), fever, odynophagia, drooling, can lead to airway obstruction	Calm the patient, intubate, drain through the posterior pharyngeal wall
Parapharyngeal	All age groups, associated with dental infections and tonsillitis	Drain through the lateral neck (to avoid damaging the carotid artery)

Watch Out

Fever, ear pain, muffled voice, and deviation of the uvula are highly suggestive of a peritonsillar abscess. This should be treated with needle aspiration and antibiotics.

Etiology/Pathophysiology

What Is the Pathophysiology of Head and Neck Cancer? What Is Field Cancerization?

Mucosa in the upper aerodigestive tract when continuously exposed to carcinogens appears grossly normal but on a histologic level will demonstrate features of dysplasia. This "field of dysplastic cells" is the bed in which malignancy develops and is referred to as field cancerization. It is thought that these dysplastic cells acquire progressive mutations and genetic alterations that result in progression to cancer; this process is termed multistage carcinogenesis.

What Is the Most Common Pathology of Head and Neck Cancer?

Squamous cell carcinoma (SCC) is identified in 90% of cases.

Work-Up

Is Observation an Acceptable Strategy for a Newly Discovered, Isolated, and Enlarged Cervical Lymph Node?

Observation is only appropriate for patients that do not present with any red-flag symptoms (e.g., dysphagia, odynophagia, dysphonia, hoarseness, weight loss) and if the lymph node has been present for less than 2 weeks. Patients should be reexamined in 2 weeks. If the node disappears, it most likely was inflammatory in nature.

In Addition to the Physical Exam Mentioned in the Vignette, What Procedure Is Performed in the Office by the Head and Neck Surgeon When a Metastatic Neck Lymph Node Is Suspected?

Flexible nasopharyngoscopy is used to evaluate the nasal cavities, nasopharynx, oropharynx, hypopharynx, and glottis to look for a site of primary tumor.

Following This Procedure, What Are the Next Steps in the Work-Up of a Neck Mass?

Radiologic imaging, laboratory studies, and tissue biopsy are typically performed concurrently and in an expedited fashion.

What Laboratory Tests Should Be Obtained?

Complete blood count (CBC), coagulation profile, liver enzymes, chemistry panel with renal function, and thyroid-stimulating hormone level.

What Initial Imaging Modality Is the Diagnostic Test of Choice to Search for the Primary Tumor?

CT scan of the head and neck with contrast is the initial preferred imaging modality to look for the primary tumor in the presence of a solitary neck mass that is concerning for metastatic malignancy. A chest X-ray is also recommended. MRI is an acceptable alternative. Ultrasound would not be useful in this setting; however, it is particularly useful in the diagnosis of congenital neck masses.

What if the Initial Head and Neck CT Scan Fails to Demonstrate the Primary Tumor, What Additional Imaging Is Recommended?

A CT scan of the chest is the next step to look for a primary lung source of the metastatic neck node. Whole-body PET scan can be helpful to identify primary site and assess for metastasis. The use of the whole-body PET as a diagnostic tool in head and neck cancer is controversial.

What Is the Best Way to Obtain a Tissue Sample to Determine if the Neck Mass Is a Metastatic Lymph Node?

Fine-needle aspiration (FNA) is the procedure of choice for a solitary neck mass that is suspicious for being a metastatic lymph node. FNA is highly sensitive and specific and is diagnostic in the majority of cases with minimal morbidity. FNA is >95% sensitive and specific when diagnostic material is obtained. FNA can yield fluid for cytology to assess for malignancy. In addition, it can facilitate gram stain, acid fast stain, and cultures. A nondiagnostic FNA should often be repeated, with or without ultrasound guidance prior to proceeding to an open biopsy.

Watch Out

Lymphoma is difficult to diagnose via FNA. If lymphoma is suspected, core needle biopsy or open biopsy should be performed.

Once FNA Confirms that the Neck Mass Is a Metastasis, What Is the Next Step in Determining the Location of the Primary Tumor?

Panendoscopy (triple endoscopy) is performed in the OR under general anesthesia. This involves a complete endoscopic evaluation of the upper aerodigestive tract, including laryngoscopy, esophagoscopy, and bronchoscopy. This is performed after other less invasive imaging modalities if no primary site can be identified. Panendoscopy allows for biopsy of the upper aerodigestive tract, including the nasopharynx, tonsils, tongue base, valleculae, post-cricoid region, and pyriform sinuses.

What Is the Role of an Open Neck Biopsy in the Evaluation of Solitary Neck Mass?

Open neck biopsies are only considered after a complete work-up has been performed with appropriate history and physical examination, imaging studies (CT vs. MRI, +/- CT PET), FNA (at least once), and panendoscopy (■ Fig. 16.1). If the neck biopsy is positive for SCC on frozen section

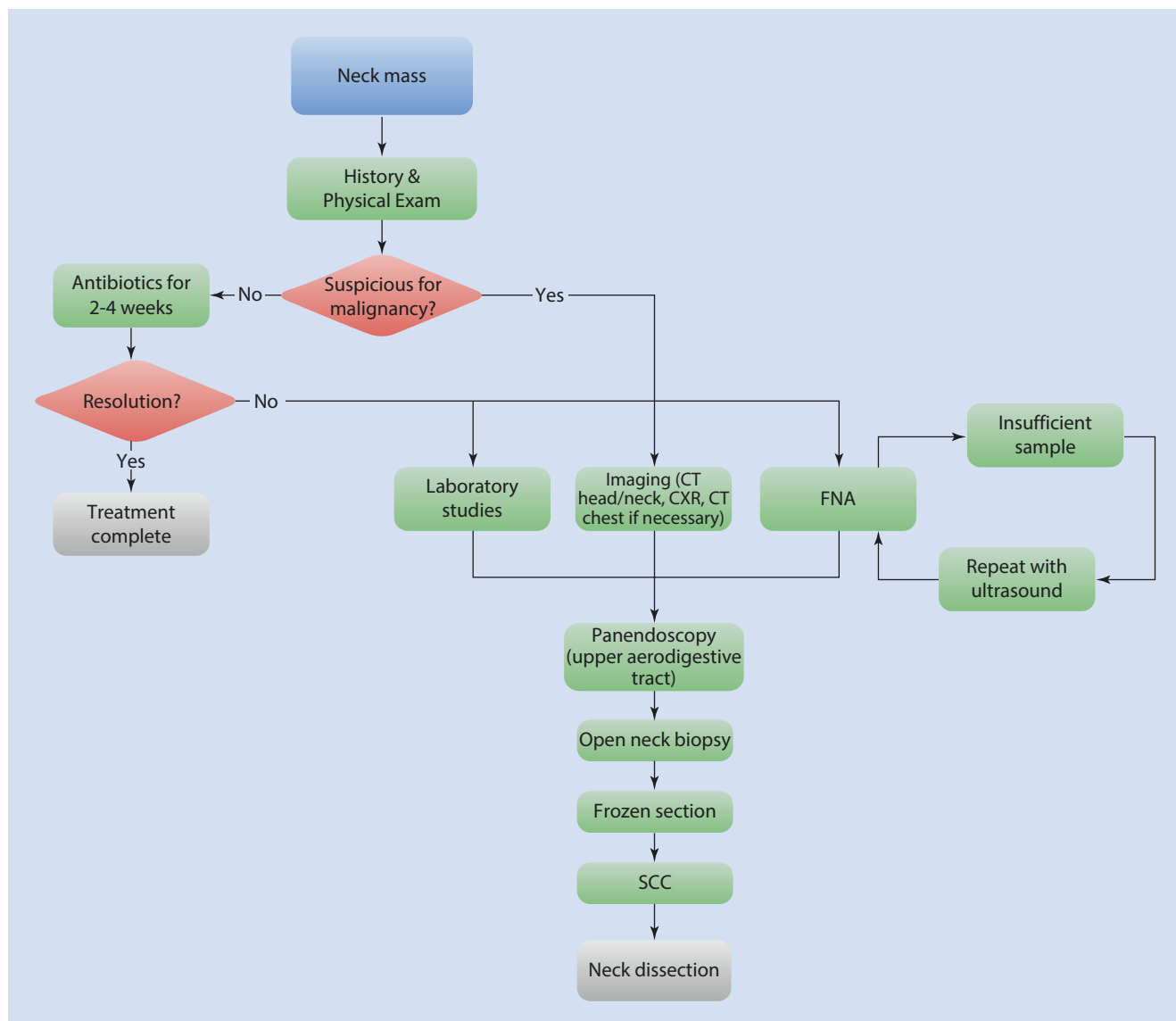


Fig. 16.1 Work-up of neck mass suspicious for malignancy: If at any point in the work-up the primary tumor is identified, treatment should be tailored to the specific site and type of the tumor. If at the

end of the diagnostic work-up no primary tumor has been identified, all sites in the head and neck should be treated

performed at the time of the biopsy, then it is imperative to proceed with a neck dissection. The reason is that open neck biopsies have been shown to be associated with increased morbidity and increased rates of local and distant recurrences, possibly from seeding tumor cells at the time of biopsy (although this dogma has been questioned in recent studies as discussed in Areas of Controversy section).

What Laboratory Studies Can Be Utilized to Assess for Infectious and Inflammatory Causes of Neck Masses?

If the history and physical examination suggest an infectious etiology, laboratory tests are obtained that include CBC, purified protein derivative (PPD), rapid plasma regain (RPR), toxoplasma, HIV, monospot, EBV, and *Bartonella* antibody.

Management

The management of head and neck cancer is dependent on the subsite and the extent of neck disease at the time of presentation. The management of head and neck malignancy is outside the scope of what is required for the surgical shelf exam.

Areas Where You Can Get into Trouble

Missing a Cancer Diagnosis

Tip-offs that move malignancy higher on the differential diagnosis include a unilateral neck mass that is progressive in size and age over 40 years. Other danger signs include unilateral otalgia, dysphagia, odynophagia, dysphonia, dyspnea,

trismus, stridor, and hemoptysis, which are concerning for advanced head and neck cancer. Pain can be associated with neural spread.

Not Recognizing Potentially Life-Threatening Signs in Advanced Stages of Cancer

Any sign of dyspnea or stridorous breathing should prompt an immediate evaluation of the airway by an otolaryngologist. Similarly, any bleeding from the mouth or hemoptysis should prompt an evaluation of the airway, as erosion into large vessels in the neck can result in airway compromise and exsanguinating hemorrhage. The patient should also be evaluated for signs that would indicate difficulty obtaining an oropharyngeal airway including trismus and obstructing lesions in the oropharynx.

Inappropriate Biopsy

It is difficult to control bleeding in the oropharynx, so biopsies in clinic should be performed with caution. Inappropriately performing an open biopsy of the neck can be problematic and is thought to potentially seed cancer cells and increase morbidity and decrease survival, although there is now some debate regarding the dangers of open biopsy (see Areas of Controversy section). Open biopsy without ruling out tuberculosis (scrofula) can also lead to chronic draining fistulas to the skin.

Areas of Controversy

The Role of Whole-Body PET in the Management of Head and Neck Cancer

The use of PET/CT is widely accepted for staging head and neck cancer and in assessing for recurrence following treatment. However, the use of PET scans in evaluating the head and neck for occult primaries has been called into question, given the high rate of false-positive results. Current guidelines suggest that a PET/CT should only be considered after all other imaging studies and a full head and neck examination are negative. The PET/CT should be done prior to panendoscopy, as manipulation of the upper aerodigestive tract can result in false positives as well.

The Role of Open Biopsy

The use of open neck biopsies has been discouraged since a study demonstrated increased morbidity, recurrence, and higher rates of distant metastasis in patients who received

open neck biopsy in the work-up of neck mass. However, recent studies have not replicated these results. Current recommendations advise at least one FNA prior to open neck biopsy. Given the high sensitivity and specificity and minimal morbidity of FNA and the possible risks of open neck biopsy, it is also reasonable to perform an image-guided repeat FNA if the first FNA is nondiagnostic. If an open biopsy is truly necessary for diagnosis, completion of neck dissection in the event of the biopsy being positive for SCC is recommended to avoid morbidity.

Summary of Essentials

History and Physical

- Red flags for malignancy in head and neck include otalgia, dysphagia, odynophagia, dysphonia, dyspnea, trismus, stridor, and hemoptysis
- Palpate the base of the tongue and the tonsillar fossa for firmness
- Always perform a complete cranial nerve exam

Etiology/Pathophysiology

- Risk factors for head and neck cancer include smoking, alcohol, age over 40 years, HPV, infection, EBV infection, GERD, Chinese ethnicity, and Plummer-Vinson syndrome
- Primary tumors of the neck include lymphoma, thyroid carcinoma, salivary gland neoplasms, schwannoma, paragangliomas, and lipomas
- Beware of deep neck abscesses: peritonsillar, retropharyngeal, and parapharyngeal

Diagnosis

- The first step in work-up is a thorough head and neck exam, including testing all cranial nerves
- Flexible endoscopy should be performed after physical exam to evaluate for a primary tumor
- FNA biopsy and CT with contrast should be performed after flexible laryngoscopy
- Further imaging such as chest CT scan, PET scan, or chest X-ray may be performed for further staging
- If indicated, panendoscopy will be performed to identify the site of primary tumor

Watch Out

- Missing diagnosis or failing to expedite work-up
- Missing danger signals of advanced head and neck cancer
- Referring for open biopsy without full work-up

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Aural Fullness, Hearing Loss, and Tinnitus

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Case Study

A 5-year-old boy is brought to the doctor by his mother because she is concerned that he may be experiencing hearing loss. Over the past several weeks, he has been turning the volume of his favorite television program louder and has been sitting closer to the television set. He has reached all his developmental milestones and is up to date with his immunizations.

When asked, the child states that he feels that his ears are always “plugged up.” His medical history includes recurrent episodes of acute otitis media. He is currently afebrile. On exam, his nasopharynx is clear, and he has no cervical lymphadenopathy. On otoscopic examination, his left tympanic membrane (TM) is immobile with an air-fluid level behind it and partial

opacification dependently. It does not appear to be erythematous. A vibrating tuning fork placed on the middle of his forehead is appreciated as louder on the left side when compared to the right. The same tuning fork, when placed on the left mastoid bone, is appreciated as louder in comparison to when it is placed near the left external auditory meatus.

Diagnosis

What Is the Differential Diagnosis for Hearing Loss in a Child?

Table 17.1

Diagnosis	History and physical
<i>Acute otitis media (AOM)</i>	Otalgia, fever, bulging, and erythematous tympanic membrane (TM) with decreased mobility, poor light reflex; duration <3 weeks
<i>Otitis media with effusion (OME)</i>	Middle ear effusion without signs of acute infection; commonly follows episode of AOM but may develop in isolation; children with OME may present with parental concerns about hearing, language development, behavior, or school performance; immobile, dull TM with air-fluid levels
<i>Chronic otitis media (COM)</i>	Recurrent or chronic ear infections that result in a perforation of the TM +/- otorrhea; higher incidence in children with cleft palate and Down's syndrome
<i>Cholesteatoma</i>	Often preceded by Eustachian tube dysfunction and COM; expansile, often cystic, collection of keratinized, desquamated epithelium in the middle ear
<i>Labyrinthitis</i>	Often preceded by a viral infection; acute onset of vertigo, gait instability, nausea, vomiting, and hearing loss; physical exam demonstrates nystagmus
<i>Otitis externa or swimmer's ear</i>	Recent contact with water; presents with a tender, swollen pinna (especially the tragus) and erythematous ear canal with possible malodorous discharge
<i>Congenital</i>	Hearing loss present at birth that may be hereditary or acquired; intrauterine (TORCH) infections
<i>Miscellaneous</i>	Cerumen impaction, foreign body, trauma

TORCH toxoplasmosis, other (syphilis, varicella-zoster, parvovirus B19), rubella, cytomegalovirus, and herpes infections

Watch Out

Cholesteatoma is a misnomer in that it does not contain fat or cholesterol but instead is secondary to desquamated keratinized epithelium. It can be very locally destructive but is not a tumor as its name suggests.

What Other Diagnoses Need to Be Considered in an Adult with Hearing Loss?

Table 17.2

Diagnosis	History and physical
<i>Exposure</i>	Work-related (e.g., construction worker, sound grip), prolonged or intense exposure to loud noises
<i>Drugs</i>	Exposure to aminoglycosides, aspirin/NSAIDs, loop diuretics, cisplatin
<i>Tumor</i>	Most common is vestibular schwannoma of the cerebellopontine angle; may present with trigeminal (paresthesia) and/or facial nerve involvement (paresis/paralysis); rarely, the only presenting symptom may be unilateral tinnitus
<i>Otosclerosis</i>	Autosomal dominant disorder affecting primarily the stapes, producing gradual ossification and conductive hearing loss; absent acoustic reflexes
<i>Ménière's disease (endolymphatic hydrops)</i>	Triad of episodic hearing loss, episodic vertigo, and tinnitus; vertigo may last for several hours (vs. seconds in BPPV); often with aural fullness
<i>Superior semicircular canal dehiscence</i>	Due to a dehiscence of the bone over the superior semicircular canal creating a “third window” where sound may escape; presents with autophony, loud sound-induced vertigo, and pressure-induced vertigo; normal acoustic reflexes

NSAID nonsteroidal anti-inflammatory drug, **BPPV** benign paroxysmal positional vertigo

What Is the Most Likely Diagnosis?

The most likely diagnosis is OME. Although this often occurs after an episode of AOM, it may also develop in isolation (discussed in ► Sect. 17.4). The predominant symptom is hearing loss and is typically discovered during school audiology screening exams or after behavioral patterns concerning for hearing loss (e.g., turning television volume louder, sitting closer to the television, replying often with “what?”). Otoscopic findings typically include an immobile or hypomobile TM and air-fluid levels with partial opacification. However, the patient should not have any signs of acute infection (more consistent with AOM). Additionally, the physical exam should be consistent with a conductive hearing loss.

Watch Out

The term otitis media (middle ear infection) is often a general diagnostic term but actually includes three different subsets of pathology involving the middle ear, AOM, OME, and COM, all of which may have very different etiologies. When describing middle ear disease, careful attention should be paid to using the most appropriate term.

History and Physical

What Is the Peak Age for OME?

The prevalence peaks at age 2 and sharply declines after age 6.

What Are the Risk Factors for OME?

Male, black race, cigarette smoke exposure, low birth weight, younger maternal age, lower socioeconomic index, shorter duration or absence of breastfeeding, and supine feeding position.

What Is the Implication of Regression in Language?

Hearing loss should be suspected in all children that present with regression or delay in language milestones. It is especially important to identify hearing loss in a timely fashion as there is a “critical period,” typically before age four, where language acquisition is most effective. In toddlers, the typical history involves a child that could babble but stops suddenly. All such children should be evaluated for hearing loss with an audiology consult. Older children may also have poor scholastic performance from being hard of hearing with poor

speech; they may benefit from sitting near the front of the class. Some persistent deficits include impairments in reading ability, hyperactive and inattentive behavior, and a lower intelligence quotient (IQ).

What Is the Implication of the Presence or Absence of Otalgia?

Otalgia, along with other acute signs or symptoms of infection (e.g., bulging and erythematous TM, fever, leukocytosis), is more consistent with AOM and less so with OME. Pain with manipulation of the outer ear suggests external canal inflammation (otitis externa).

Watch Out

Any pediatric patient with a *unilateral* aural fullness or otalgia should be suspected of having a foreign body obstruction. In fact, any unilateral head and neck lesion in a pediatric patient (e.g., unilateral rhinorrhea, unilateral wheezing) should be appropriately evaluated for a foreign body.

What Is the Importance of Otorrhea?

Otorrhea is concerning for middle ear pathology with TM perforation, though it may be present in otitis externa as well. Careful attention should be paid to the characteristics of the drainage which varies from appearing thin/clear/serous, mucoid, bloody to purulent, all of which suggest different etiologies. Some patients with otalgia will report resolution of pain followed by new-onset otorrhea. This sequence of symptoms is highly suggestive of a TM perforation. Failure to resolve drainage after conservative management may require surgical intervention.

How Does One Distinguish Between Otitis Externa and Otitis Media on History and Physical Exam?

Otitis externa (“swimmer’s ear”) typically occurs in patients following exposure to warm water but may also appear after recent ear instrumentation. The most common symptoms include otalgia upon manipulation of the external ear (e.g., touching the tragus), pruritus, and hearing loss. On otoscopic examination, a patient with otitis externa will appear to have an edematous and erythematous external ear canal. If able to be examined, the TM is typically intact and freely mobile with no evidence of air-fluid levels (i.e., normal).

What Are Some Abnormal Features Found on Otoscopic Examination that May Help Distinguish AOM from OME?

Table 17.3

Feature	AOM	OME
Immobility	Yes	Yes
Air-fluid level	Rare	Yes
Opacification	Yes	Yes
Bulging/fullness	Yes	No
Erythematous	Yes	No

What Is the Main Symptom Seen with OME?

Conductive hearing loss secondary to fluid within the middle ear space. The presence of an air-fluid level or visible bubbles within the middle ear space is associated with less hearing loss. Aside from hearing loss, patients with OME may also have sleep disturbance, ear fullness, tinnitus, or even balance problems.

The Majority of OME Cases Spontaneously Resolve Within What Period of Time?

Over 50% of OME cases spontaneously resolve within 3 months. Those that continue for longer are less likely to resolve without intervention.

Etiology/Pathophysiology

What Is the Most Likely Etiology for Sudden Deafness?

Sudden deafness is most often due to viral infections and leads to sensorineural hearing loss. The most common viruses are herpes simplex and herpes zoster. Although hearing loss may be permanent, approximately 1/3 of patients regain normal hearing in 2 weeks. High-dose empiric steroids for 10–14 days are the mainstay of treatment with repeated audiograms performed to track recovery and treatment efficacy.

What Are the Two Main Causes of OME?

AOM or isolated Eustachian tube dysfunction (ETD). Residual fluid from suppurative AOM can lead to OME in 50% of patients after 1 month and 10% of patients after

3 months. The fluid is believed to result from chronic inflammation triggered by the presence of bacterial components already present in the middle ear. This inflammatory state leads to upregulation of mucin-rich secretions with impairment of effluent clearance. OME may also be secondary to isolated ETD. This can occur as a result of anatomic blockage from inflammation secondary to allergies, upper respiratory infection (URI), and trauma. The impaired clearance of secretions and lack of pressure equalization between the middle ear and external environment in ETD leads to the production of transudate from the mucosa with the accumulation of a serous and essentially sterile effusion.

Watch Out

Regardless of the cause of acute otitis media, Eustachian tube dysfunction is nearly universal in OME.

What Other Diagnoses Need to Be Considered in an Adult with OME?

OME is rare in adults, as the Eustachian tube tends to lengthen and become more vertically oriented with age. Thus, it is less sensitive to local irritation and mucosal swelling. In the absence of a history of recurrent ear infections, unilateral OME in an adult should be considered cancer obstructing the Eustachian tube until proven otherwise and should prompt consultation with an otolaryngologist.

Watch Out

Nasopharyngeal carcinoma, though rare, often presents with unilateral OME. It is associated with Epstein-Barr virus (EBV) and has a high incidence in certain regions of China. Nasopharyngoscopy should be performed in all adults with OME.

What Is the Role of the Eustachian Tube (ET), and How Does It Differ Between Adolescents and Adults?

The ET serves to (1) maintain gas pressure homeostasis within the middle ear by equalizing the pressure across the TM, (2) help prevent infection of the middle ear and reflux of contents from the nasopharynx, and (3) clear middle ear secretions. It fulfills this role by maintaining the capacity to open and close appropriately. Children less than 6 years of age have a shorter, more horizontal ET, lined by a floppier elastic cartilage. Children with Down's syndrome and cleft palate are also more prone to ETD. Additionally, the presence of adjacent adenoid tissue, which tends to enlarge during childhood and regress in puberty, predisposes a child to obstruction of the ET and reflux of nasopharyngeal contents. The ET becomes more adult-like around 6 years of age.

Which Pathogens Are Most Commonly Found in OME?

The same bacterial organisms found in patients with AOM can be isolated in patients with OME. These include *Streptococcus pneumoniae*, non-typeable *Haemophilus influenzae*, and *Moraxella catarrhalis*. Other microbes may include *Pseudomonas aeruginosa* (more common with otitis externa), *Streptococcus pyogenes*, and other anaerobes.

Watch Out

The HiB-conjugated vaccine does not cover non-typeable *Haemophilus*, so it does not prevent otitis media.

What Is the Most Significant Complication that May Result from OME?

Conductive hearing loss. Frequent recurrence of middle ear infections may also result in TM scarring and damage, known as tympanosclerosis, which becomes problematic when the ossicular chain is involved. With persistence of ETD and a negative middle ear pressure, a retracted TM overtime may result in erosion of the middle ear ossicles, TM perforation, and even cholesteatoma formation (e.g., accumulation of epithelium/keratin within the middle ear).

Watch Out

Tympanosclerosis is hyaline and calcium deposition within the TM and middle ear mucosa secondary to infection or trauma.

Workup

What Does a Pneumatic Otoscopy Allow the Clinician to Do? How Is It Used?

The finding of a middle ear effusion is key in establishing the diagnosis of OME. Yet middle ear effusion is not always obvious on otoscopy. Traditionally, the determination of an effusion in equivocal cases has required the performance of a myringotomy (the surgical creation of a small hole in the TM). Pneumatic otoscopy allows for direct, dynamic assessment of TM mobility in response to pressure changes.

What Two Tests Will Help Differentiate a Conductive Hearing Loss from a Sensorineural Hearing Loss? How Are They Performed?

Weber and Rinne tests. Both of these tests utilize a tuning fork (512 Hz) to distinguish between sensorineural hearing loss (SNHL) and conductive hearing loss (CHL). Prior

to performing, ensure that the ear canals are free of cerumen. The Weber test places the vibrating tuning fork on the forehead or bridge of the nose. The vibrations transmit through the skull and should be heard equally among both ears. Unilateral SNHL lateralizes to the unaffected ear, while unilateral CHL lateralizes to the affected ear. The Rinne test compares air and bone conduction. The 512 Hz tuning fork is placed by the ear canal and then on the mastoid process. The patient is then asked which is louder, the canal (air conduction) or mastoid (bone conduction). A positive or normal Rinne test demonstrates air greater than bone conduction. A negative test demonstrates bone greater than air conduction as is seen with CHL. For example, with a right CHL, one would observe Weber right and Rinne negative on the right. Of course, one can and should also obtain a formal audiogram, upon which a CHL, typically of less than 30 dB, would be observed for OME.

Management

In Children, What Is the Management for the Majority of Cases of OME?

The majority of cases of OME spontaneously resolve within 3 months, without medical or surgical intervention. Additionally, up to another 30% will resolve after 6 months. As such, for children not at risk for speech, language, and learning difficulties, it is recommended to wait and observe for a 3-month period. In children with mild hearing loss, the clinician should instruct the family on methods to optimize the listening and learning environment until OME resolution. This includes preferential classroom seating, speaking close and clearly to the patient, and repeating oneself when needed.

What Is Autoinflation? Is There a Role for It in OME?

Autoinflation is a simple method that can be employed to raise pressure within the nose in order to reopen the ET and may be useful in cases of ETD. It can be performed by holding the nose and mouth closed while forcibly exhaling. The idea is to open the ET to introduce air into the under-aerated middle ear to equalize pressures across the TM and promote drainage of middle ear fluid. Autoinflation is a low-cost method with rare adverse effects that can be trialed while awaiting spontaneous resolution.

Are Antihistamines and/or Decongestants Recommended for OME in Children? How About Steroids or Antibiotics?

No. The use of antihistamines, decongestants, and/or combination therapies has not been shown to demonstrate any benefit in children with OME. Oral steroids used alone or in

combination with antibiotics appear to accelerate the short-term resolution of OME, but no long-term evidence exists in regard to lasting benefits or hearing improvement for either oral or intranasal steroid use.

Should Antibiotics Be Used Routinely for Patients with OME?

Although a bacterial pathogen can be isolated in the middle ear fluid in roughly 1/3 of children with OME, the routine use of antibiotics is not recommended because the potential side effects from extraneous antibiotic exposure (i.e., antibiotic resistance) outweigh any benefit gained by a small subset of patients.

What Are the Indications for Tympanostomy Tube Insertion?

Tympanostomy tubes, also referred to as ventilation tubes, pressure equalization (PE) tubes, and grommets, are placed through a myringotomy (incision in the TM). They provide for middle ear ventilation and may last for several months to years. Indications for which PE tubes should be placed include bilateral OME with hearing impairment; OME with poor school performance, behavioral problems, otalgia, or reduced quality of life; and recurrent AOM with OME.

How Does the Management of OME Differ in Adults?

Although OME is well documented in the pediatric population and is fairly benign, its presence in adults is more ominous, particularly when it is unilateral in nature. Similar to their pediatric counterparts, OME in adults ultimately result from ETD. This may be secondary to obstruction from a tumor near the openings of the Eustachian tubes (e.g., nasopharyngeal carcinoma), enlarged tonsils/adenoids, or a rapid change in air pressure (barotrauma) after a plane flight or scuba dive. As such, management should be guided by a careful history and physical exam with close attention paid to any lesions that may be obstructing the ET. Nasopharyngoscopy can help visualize the nasopharynx and openings of the ET. Additionally, any unilateral effusion developing in an adult without a history of ear problem should be immediately referred to a head and neck surgeon, as the implications may be serious.

What Are the Long-Term Complications from Untreated Otitis Media?

Permanent hearing loss, ruptured TM, mastoiditis, temporal bone osteomyelitis, meningitis, sigmoid sinus thrombosis, or brain abscess

Summary of Essentials

History and Physical

- AOM: Otalgia, fever, hearing loss, tinnitus, bulging and erythematous TM with decreased mobility, and poor light reflex; less than 3 weeks
- OME: Middle ear effusion without signs of acute infection; commonly follows episode of AOM but may develop in isolation; predominant symptom is hearing loss
- COM: Recurrent or chronic ear infections that result in perforation of the TM +/- otorrhea; higher incidence in children with cleft palates
- Otitis externa: Recent contact with warm water; presents with a tender, swollen pinna, and erythematous ear canal +/- discharge; normal TM
- Regression in language may be a sign of early hearing loss

Pathophysiology

- Eustachian tube has three roles:
 - Maintains gas pressure homeostasis within the middle ear
 - Prevents infection of the middle ear and reflux of contents from the nasopharynx
 - Clears middle ear secretions
- AOM: Acute infection typically caused by *Streptococcus pneumoniae*, non-typeable *Haemophilus influenzae*, and *Moraxella catarrhalis*
- OME – two main causes:
 - Results from residual fluid from suppurative AOM
 - Isolated ETD
- Nasopharyngeal carcinoma, though rare, often presents with unilateral OME in adults.
 - Associated with EBV
 - Higher incidence among Chinese patients

Workup

- AOM and otitis externa best diagnosed with history and physical.
 - Otoscopy to characterize ear canal contents and TM
- OME.
 - Pneumatic otoscopy less invasive than myringotomy
 - In adults, nasopharyngoscopy to evaluate for tumors obstructing ET
- Weber and Rinne tests help differentiate SNHL vs. CHL

Management

- AOM: antibiotics
- OME: majority of cases do not need any medical or surgical intervention
 - PE tubes are indicated for symptomatic OME lasting at least 3 months

- PE tubes for recurrent AOM with OME
- PE tubes if bilateral OME with hearing impairment
- PE tubes if any OME with vestibular problems, poor school performance, behavioral problems, otalgia, or reduced quality of life

Complications

- The most significant complication of OME is conductive hearing loss
- Long-term complications of untreated OME include permanent hearing loss, ruptured TM, mastoiditis, temporal bone osteomyelitis, meningitis, sigmoid sinus thrombosis, or brain abscess

Watch Out

- Any pediatric patient with a unilateral aural fullness or otalgia should be suspected of having a foreign body obstruction

- Any delay in language milestones or regression should be properly evaluated for hearing loss with an audiology consult

Suggested Reading

- American Academy of Family Physicians, American Academy of Otolaryngology-Head and Neck Surgery and American Academy of Pediatrics Subcommittee on Otitis Media with Effusion. Otitis media with effusion. *Pediatrics*. 2004;113:1412–29.
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Question Set: Head and Neck

Questions

1. A 28-year-old man presents for a routine annual physical exam. He has no significant past medical history. His temperature and vitals are stable, and his laboratory examination is benign. He smokes one pack per day. On physical examination, he has a freely moving 2 cm cervical lymph node. What is the best next step in management?
- (A) Fine-needle aspirate (FNA)
 - (B) CT scan of the head and neck with contrast
 - (C) CT scan of the head and neck without contrast
 - (D) Observation and follow-up in 3 weeks
 - (E) Panendoscopy
2. A 4-year-old boy is brought to the emergency department by his parents for difficulty breathing. His mother reports that he developed nasal congestion and malaise 2 days ago, but over the past 12 hours, he has had continuous low-pitched coughs. His temperature is 38.4 °C. On physical exam, he has pharyngeal erythema, cervical lymphadenopathy, and inspiratory stridor. Neck radiograph shows subglottic narrowing of the airway. He appears to be in respiratory distress and subsequently requires rapid sequence intubation. What is the most likely diagnosis?
- (A) Respiratory distress syndrome
 - (B) Epiglottitis
 - (C) Laryngotracheobronchitis
 - (D) Bronchiolitis
 - (E) Laryngomalacia
3. Where is the most likely location of a foreign body obstruction in a patient younger than one?
- (A) Right main stem bronchus
 - (B) Left main stem bronchus
 - (C) Upper trachea
 - (D) Carina (cartilaginous ridge in the lower trachea)
 - (E) Larynx
4. A 45-year-old male presents with a mass in his face, just below his ear. He denies any symptoms. On physical exam, the mass appears to be within the parotid gland. The mass feels firm, non-tender, and somewhat mobile. The facial nerve is intact. There is no additional mass inside the mouth. The mass most likely represents a:
- (A) Pleomorphic adenomas (mixed tumor)
 - (B) Papillary cystadenoma (Warthin's tumor)
 - (C) Mucoepidermoid carcinoma
 - (D) Adenoid cystic carcinoma
 - (E) Oncocytoma
5. A 34-year-old female presents with soreness and chronic inflammation of her tongue and difficulty swallowing, stating that she feels like she is choking, particularly when eating solid foods. Laboratory examination is significant for a hemoglobin of

10. A 65-year-old male is diagnosed with squamous cell laryngeal cancer. Examination of the neck reveals no adenopathy. At the time of biopsy, the cancer is determined to be small, and the vocal cord is still moving. It is determined that the laryngeal cancer is likely an early stage. Which of the following would be recommended next?
- (A) Chest X-ray
 - (B) MRI
 - (C) PET scan
 - (D) Bronchoscopy
 - (E) No additional imaging needed
11. A 9-year-old male with a past medical history of acute myeloid leukemia (AML) treated with bone marrow transplant presents with right ear pain and a headache. His vaccination history is not available. His mother reports that the pain started 3 days ago and is accompanied by pruritus and a sensation of fullness in the ear. His headache began suddenly and has gotten worse over the past 2 h. Otoscopic examination reveals a green/gray discharge, an erythematous ear canal, and a normal-appearing tympanic membrane. What is the most likely organism responsible for this patient's presentation?
- (A) *Streptococcus pneumoniae*
 - (B) *Haemophilus influenzae*
 - (C) *Moraxella catarrhalis*
 - (D) *Mycoplasma*
 - (E) *Aspergillus niger*
12. A 60-year-old man arrives to the emergent department complaining of fevers, neck pain, extreme thirst, and difficulty breathing. He has several rotted teeth extracted recently. On physical examination, his temperature is 38.9 °C, heart rate is 120/min, respiratory rate is 24/min, and blood pressure is 120/70 mmHg. He has a strong smell of alcohol on his breath. He appears agitated, and his breathing is labored. His voice sounds brassy. He is leaning forward and spitting up his saliva. On physical exam his neck is markedly swollen on the left side just below his mandible. The overlying skin is red. No fluctuance is palpated. He is unable to open his mouth. What is the best next step in management?
- (A) Immediate incision and drainage at bedside
 - (B) Laryngoscopy
 - (C) Broad-spectrum antibiotics
 - (D) Vigorous fluid hydration
 - (E) Establish airway
13. A 50-year-old male smoker presents with a 2 cm lymph node in his left mid neck that he states has been present for 8 weeks. He denies any symptoms. Flexible nasopharyngoscopy in the office is negative. CT of the neck and chest is negative. Fine-needle aspirate (FNA) of the node confirms metastatic squamous cell carcinoma. What is the next best step in the management?
- (A) Excision of lymph node
 - (B) Modified radical neck dissection
 - (C) Laryngoscopy
 - (D) Radiation and chemotherapy
 - (E) Laryngoscopy, esophagoscopy, and bronchoscopy with random biopsies
14. A 6-year-old boy presents to the emergency department with fevers, hearing loss, and ear pain. He finished a 10-day course of amoxicillin 1 day ago to treat an episode of acute otitis media. His ear pain initially resolved after starting antibiotics but came back 2 days ago and is now localized behind the ear. His temperature is 38.3 °C, blood

to airway compromise from the swollen epiglottitis. Bronchiolitis is characterized by a viral infection of the bronchioles and occurs most commonly in patients less than 2 years old (D). Laryngomalacia is a congenital abnormality of the laryngeal cartilage and can result in collapse of the supraglottic structures in newborns, leading to airway obstruction (E). Infants with laryngomalacia should be fed upright and remain in this position for at least 30 min after each feed.

- ✓ 3. Answer E
The larynx is the most common site for foreign body aspiration in children younger than one, while the trachea and right main stem bronchus are the most common sites in older children (A, C–D). The left main stem bronchus is a less frequent site for foreign body aspiration owing to its acute angle as it enters the lung versus an obtuse angle in the right (B). Patients with foreign body aspiration may have wheezing, but using a bronchodilator increases the risk of further pushing the foreign body down the airway. Order a chest X-ray if there is a suspicion for a foreign body obstruction. Bronchoscopy is recommended for definitive diagnosis. Extracting the foreign body requires a *rigid* bronchoscopy.
- ✓ 4. Answer A
Most salivary gland tumors are in the parotid gland, and the majority are benign (80%). The most common type of parotid gland tumor is a pleomorphic adenoma. Although benign, it does have a known risk of malignant transformation that becomes as high as 10–25% when present beyond 15 years. Warthin's tumor is the second most common benign salivary tumor, may be bilateral, and is strongly related to smoking (B). Mucoepidermoid carcinoma is the most common malignant salivary gland tumor (C). Facial nerve involvement is more suggestive of malignant transformation. The second most common malignancy is adenoid cystic carcinoma (D). Oncocytoma is a rare (1–2%) salivary gland tumor and most often involves the parotid gland (E).
- ✓ 5. Answer E
The triad of dysphagia, esophageal webs (e.g., feeling of choking with solid foods), and iron-deficiency anemia is highly suggestive of *Plummer-Vinson syndrome*. The pathophysiology still remains unclear but is most likely multifactorial. Barium esophagram is one of the most sensitive methods and diagnostic tests of choice to confirm the presence of esophageal webs, which appears as a thin projection off the postcricoid, anterior esophageal wall. If esophagram is equivocal, esophagoscopy can be used next (D). Laryngoscopy or bronchoscopy is not typically required in the workup for Plummer-Vinson syndrome (A–C). However, if there is any concern for head and neck cancer (e.g., neck mass in patient with smoking history), a panendoscopy can be considered in the workup.
- ✓ 6. Answer D
In an older (>50) male patient with a history of smoking, presenting with persistent laryngitis and recent difficulty in projecting his voice, laryngeal cancer must be ruled out. The initial test is to evaluate the larynx and vocal cords with indirect laryngoscopy in the office (with administration of local anesthetic spray to the back of the throat). It is termed indirect, as it has a mirror that permits indirect visualization of the vocal cords. Structural abnormalities, such as masses, ulcers, or mucosal irregularities, may be noted, as well as motion of the vocal cords. Direct laryngoscopy is done in the operating room under general anesthesia (E). It involves insertion of a rigid metal tube directly into the larynx and allows for biopsies to be taken. Given the high likelihood of cancer, antibiotics or reassurance would be inappropriate (B–C).
- ✓ 7. Answer C
Although it occurs infrequently, brain abscesses are a complication of acute otitis media. It shows many of same manifestations as a brain tumor (space occupying) but with a much shorter timetable (1–2 weeks). Patients typically have a fever, acute onset

✓ 11. Answer E

This patient most likely has malignant otitis externa secondary to otomycosis. *Aspergillus niger* is the most common cause of otomycosis and can present very similarly to otitis externa. However, patients with otomycosis will complain of an intense fullness in the ear and pruritus, and physical exam will be significant for a gray exudate from the affected ear. Unlike otitis media, patients with otomycosis will have a normal-appearing tympanic membrane as this typically affects the external ear canal. The two high-risk populations for malignant otitis externa secondary to otomycosis include patients with AML or diabetic ketoacidosis. Depending on the extent of local spread, patients can present with a myriad of symptoms including blindness, headache, seizure, and coma. CT scan of the head will help evaluate the extent of damage and infiltration and help guide surgical management (e.g., debridement, washout). Answer choices A–C are all common causes of otitis media with *Streptococcus pneumoniae* being the most common organism. *Mycoplasma* has been associated with bullous myringitis, which is characterized by vesicular inflammation of the tympanic membrane and is seen most commonly with untreated otitis media (D). Patients will present with very tender ear canals, and otoscopy shows large red vesicles on the tympanic membrane.

✓ 12. Answer E

Ludwig's angina is characterized by a progressive cellulitis in the floor of the mouth and often involves the submandibular space (which is divided by the mylohyoid muscle). It can present with fevers, neck pain, neck swelling, dental pain, dysphagia, and drooling. This can be life-threatening as it can lead to airway obstruction. The majority of cases follow dental procedures which allow bacteria from a tooth infection to migrate into the submandibular space. Patients with labored breathing and marked swelling require an immediate airway. This may be achieved via endotracheal intubation or alternatively via a surgical airway (cricothyroidotomy or tracheostomy). The neck infection will then need immediate surgical drainage, but this is best accomplished in the operating room (A). Broad-spectrum antibiotics and IV fluids are also necessary but should not be prioritized over the airway (C–D). Laryngoscopy is not recommended as it will only delay establishment of the airway, and any potential trauma/gagging may further compromise the airway (B).

✓ 13. Answer E

A solitary enlarged lymph node that persists beyond 3 weeks particularly in a middle-aged male smoker should be considered a metastatic lymph node until proven otherwise. Oftentimes, the patient will have symptoms (such as hoarseness, persistent sore throat, ulcerative lesions) that will guide the workup. But if no symptoms are present, a flexible nasopharyngoscopy is used initially to evaluate the nasal cavities, nasopharynx, oropharynx, hypopharynx, and glottis to look for a site of primary tumor. FNA is subsequently performed to confirm that the solitary neck mass is a metastatic lymph node. Once FNA confirms this, CT scan of the neck may identify the primary tumor. If the primary is still not evident, the next step is to try to identify the location of the primary tumor using a panendoscopy or triple endoscopy with random biopsies. This involves a complete endoscopic evaluation of the upper aerodigestive track, including laryngoscopy, esophagoscopy, and bronchoscopy under general anesthesia in the operating room (C). A neck dissection would not be considered until after panendoscopy (B). Radiation and chemotherapy may be used as adjuncts depending on the stage and grade of the primary tumor (D).

✓ 14. Answer C

Mastoiditis usually occurs days to weeks after an episode of acute otitis media. Patients present with fevers and complaints of a red, swollen, and tender area behind the ear (mastoid process). Physical exam may reveal a displaced ear on the affected side. The diagnosis can be confirmed with a CT scan of the mastoid process and is recommended for patients suspected of having mastoiditis. Patients with CT-confirmed acute surgical mastoiditis are candidates for mastoidectomy with insertion of a tym-

Hepatopancreaticobiliary

Matthew Y. C. Lin

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Postprandial Right Upper Quadrant Pain

Manan P. Shah, Matthew Y. C. Lin, and Christian de Virgilio

Case Study

A 40-year-old, gravida six and para six, moderately obese Hispanic female presents to the emergency department with a 1-day history of constant epigastric and right upper quadrant (RUQ) pain. She describes the severity of the pain as a 7 out of 10. The pain began after eating fried pork. She reports that the pain also seems to affect the right side of her back near her scapula.

She feels nauseated and has vomited twice. She has had similar pain, but of lesser severity and duration, several times over the past year, usually after eating fatty, spicy foods. On physical examination, her temperature is 38 °C, heart rate is 110/min, and her blood pressure is 120/80 mmHg. She has marked tenderness to palpation in the RUQ of her abdomen. After being instructed to

take a breath, deep palpation of her RUQ causes her to abruptly cease inspiration due to pain. The remainder of the abdominal examination is benign. Laboratory studies are remarkable for leukocytosis of $14 \times 10^3/\mu\text{L}$ (normal $4.1\text{--}10.9 \times 10^3/\mu\text{L}$), total bilirubin 1.0 mg/dL (0.1–1.2 mg/dl), alkaline phosphatase 70 u/L (33–131 u/L), amylase 60 u/l (30–110 u/L), and lipase 30 u/L (7–60 u/L).

Diagnosis

What Is the Differential Diagnosis?

Table 18.1

Diagnosis	History and physical
<i>Symptomatic cholelithiasis</i>	RUQ pain radiating to the back after fatty meals, resolves within a few hours, female, multigravida, obese
<i>Acute cholecystitis</i>	Severe RUQ pain radiating to back +/- scapular pain, persistent (>4–6 hours), fever, tachycardia, <i>Murphy's sign</i>
<i>Choledocholithiasis</i>	RUQ pain with jaundice but no systemic inflammatory signs (no fever or leukocytosis)
<i>Sphincter of Oddi dysfunction</i>	Episodic RUQ pain aggravated by opioids
<i>Acute cholangitis</i>	Persistent RUQ pain, fever, jaundice (<i>Charcot's triad</i>)
<i>Acute pancreatitis</i>	Severe epigastric pain radiating straight through to back (secondary to cholelithiasis, alcohol abuse)
<i>Acute gastritis</i>	NSAID use, steroid use, gnawing epigastric pain
<i>Peptic ulcer disease</i>	Intermittent burning epigastric pain that improves (duodenal ulcer) or worsens (gastric ulcer) with food intake (secondary to <i>H. pylori</i> infection, NSAID, steroid use)
<i>Malignancy</i>	Gallbladder (<i>porcelain gallbladder</i>), pancreatic (<i>Courvoisier sign</i>), bile duct; chronic pain, weight loss, fatigue; +/- painless jaundice, pale stools, dark urine, pruritus
<i>Fitz-Hugh-Curtis syndrome</i>	RUQ pain; history of recent pelvic inflammatory disease (either <i>Chlamydia trachomatis</i> or <i>Neisseria gonorrhoeae</i>), fever, "violin string" adhesions between liver and diaphragm
<i>Acute hepatitis</i>	Hepatitis A (recent foreign travel, IVDA, raw shellfish, fecal-oral)
<i>Hepatic abscess</i>	RUQ pain, high fever, hepatomegaly (bacterial or amoebic)
<i>Myocardial infarction</i>	Epigastric pain (referred pain), diabetes, cardiovascular disease, hypercholesterolemia
<i>Acute pyelonephritis</i>	Costovertebral angle tenderness, dysuria, hematuria

NSAID nonsteroidal anti-inflammatory drug, IVDA intravenous drug abuse

What Is the Most Likely Diagnosis?

With her current history of severe persistent abdominal pain following ingestion of fatty foods, nausea and vomiting, and associated right upper quadrant tenderness to palpation, the etiology is most likely of biliary origin. The patient's prior history is consistent with symptomatic cholelithiasis. With a positive Murphy's sign, fever, tachycardia, and elevated white blood cell (WBC) count, the most likely diagnosis is acute cholecystitis. With a normal total bilirubin and alkaline phosphatase, choledocholithiasis and acute cholangitis

are less likely. Similarly, a normal amylase and lipase rule out gallstone pancreatitis.

History and Physical

Why Is the Term Biliary Colic a Misnomer? What Is a Better Term?

Colicky pain typically waxes and wanes, with periods of intense pain (such as from a ureter intermittently contracting in the presence of a renal stone) followed by relief. The

pain from gallstones is constant, may last from minutes to hours, and then dissipates. A more correct term is symptomatic cholelithiasis.

Why Is It Important to Distinguish Between Symptomatic Cholelithiasis and Acute Cholecystitis?

Symptomatic cholelithiasis is usually managed as an outpatient, with eventual elective laparoscopic cholecystectomy. Acute cholecystitis requires hospital admission, intravenous (IV) antibiotics, and urgent cholecystectomy.

How Does One Clinically Distinguish Between Symptomatic Cholelithiasis and Acute Cholecystitis?

Table 18.2

	Symptomatic cholelithiasis	Acute cholecystitis
History	RUQ pain usually resolves within minutes to 3–4 hours	Unremitting RUQ pain >6 hours, associated nausea/vomiting
Physical exam	Mild RUQ tenderness to palpation	Murphy's sign
Vital signs	Normal	Fever, tachycardia
Laboratory values	Normal white blood cell count	Elevated white blood cell count with left shift
Ultrasound findings	Gallstones	Gallstones, gallbladder wall thickening >4 mm, pericholecystic fluid, sonographic Murphy's sign

Pathophysiology

What Is the Significance of Abdominal Pain After Eating Fatty Foods?

It suggests a biliary origin of the pain. Fatty food ingestion triggers the release of cholecystokinin (CCK), which leads to contraction of the gallbladder. Gallstones may obstruct the cystic duct so that the gallbladder is unable to empty bile as it attempts to contract. The ensuing distention of the gallbladder stretches the visceral peritoneum that surrounds it, leading to RUQ and/or epigastric pain that is vague and mild to moderate in severity (symptomatic cholelithiasis).

What Is the Significance of RUQ Pain Combined with Scapular Pain?

The scapula and the soft tissue surrounding the gallbladder receive sensory innervation from the same spinal cord levels. The scapula is innervated by the supraclavicular nerves, and the soft tissue surrounding the gallbladder is innervated by the phrenic nerve. Since the same spinothalamic pathways (pain and temperature) from both nerves travel to the same cervical cord levels, gallbladder distention/inflammation leads to referred scapular pain.

What Is the Significance of the Patient's Inspiration Stopping with RUQ Palpation?

This physical examination finding is called *Murphy's sign* and is thought to be specific to acute cholecystitis. It represents focal peritonitis of the anterior abdominal wall parietal peritoneum due to inflammation of the adjacent gallbladder. When the patient inspires, the diaphragm and therefore the gallbladder move caudad (inferiorly). Palpating deep in the RUQ causes the gallbladder to come into contact with the anterior abdominal wall, further irritating the inflamed parietal peritoneum and causing cessation of inspiration due to the sudden increase in pain.

Watch Out

Do not confuse Murphy's sign with McMurray's sign, which is a palpable or audible snap occurring when extending a fully flexed knee while applying tibial torsion. A positive McMurray's sign indicates a medial meniscal tear.

What Is the Difference Between Visceral and Somatic Pain?

Visceral pain tends to occur first. It is caused by stretching of the peritoneum surrounding an organ (or ischemia). It tends to be vague and less localizable. Somatic pain occurs when the inflammation extends to the adjacent peritoneum lining the abdominal wall. It is well localized and typically severe. Patients can often point to where it hurts, and it is elicited as guarding and rebound on physical examination.

What Is the Clinical Significance of the Patient's Low-Grade Fever, Tachycardia, and Leukocytosis?

The presence of systemic signs and of a systemic inflammatory response, such as fever, tachycardia, and leukocytosis, suggests a more severe biliary disease such as acute cho-

lecystitis or acute cholangitis. Symptomatic cholelithiasis (biliary colic) does not typically present with a systemic response.

What Is Chronic Cholecystitis?

Recurrent bouts of symptomatic cholelithiasis often lead to chronic inflammation of the gallbladder with fibrotic changes seen on histologic examination. As such, biliary colic, symptomatic cholelithiasis, and chronic cholecystitis are interchangeable terms.

What Exactly Causes Acute Cholecystitis?

Acute cholecystitis is caused by sustained obstruction (impaction) of the cystic duct, most often by a gallstone. This obstruction leads to inflammation and edema of the gallbladder wall and then eventually bacterial overgrowth and invasion of the gallbladder wall. This may lead to ischemia, and necrosis (gangrenous cholecystitis), and rarely gallbladder perforation.

What Is Hydrops of the Gallbladder?

In some patients, chronic obstruction of the cystic duct does not lead to acute cholecystitis. In this setting, the gallbladder mucosa continues to secrete mucus, and the bile in the gallbladder eventually gets reabsorbed, leaving a glycoprotein-rich white fluid, sometimes called “white bile.”

What Are the Typical Pathogens in Bile?

The most common organisms found in biliary cultures from patients with acute cholecystitis are, in order, *Escherichia coli*, *Klebsiella*, *Bacteroides fragilis*, *Enterobacter*, *Enterococcus*, and *Pseudomonas* species.

What Are the Components of Bile?

The three main components of bile are bile salts, cholesterol, and lecithin (a phospholipid). Bile also contains water, electrolytes, proteins, and bile pigments.

What Are the Two Main Types of Gallstones?

The two main types of gallstones are cholesterol (70–80% of gallstones in the USA) and pigmented.

What Are the Main Risk Factors for Developing Cholesterol Gallstones?

- Lithogenic bile
- Increased estrogen (females, pregnancy, oral contraceptive use): increases cholesterol in bile and decreases gallbladder motility
- Obesity, Crohn’s disease, and terminal ileal resection: decreases bile salts
- High-fat diet, hyperlipidemia: increases bile cholesterol
- Rapid weight loss after gastric surgery, vagotomy, somatostatin therapy, total parenteral nutrition: impairs gallbladder emptying and/or causes biliary sludging
- Hispanic, Pima Indians: hereditary predisposition to biliary disease

Watch Out

Patients with biliary disease often have the 4 “Fs” (female, fat, forty, fertile)

How Do Cholesterol Gallstones Form?

Cholesterol gallstones form when the concentration of cholesterol in the bile exceeds its solubility, which causes precipitation of cholesterol crystals. The solubility of cholesterol is dependent on the concentration of cholesterol, bile salts, and lecithin in the bile. High concentrations of cholesterol or lower concentrations of bile salts or lecithin lead to precipitation of cholesterol stones.

How Do Pigmented Gallstones Form?

Pigmented stones are classified as black or brown and contain less than 30% cholesterol. The dark coloration is a result of the presence of calcium bilirubinate within the stones. *Black stones* are often associated with hemolytic diseases such as hereditary spherocytosis, sickle cell disease, or G6PD deficiency. The breakdown of red blood cells leads to an increase in unconjugated bilirubin, driving the formation of black stones. Black stones are most often found within the gallbladder. *Brown stones*, in comparison, are larger and softer and most often form within the bile ducts. They are usually associated with bacterial infection or parasites (e.g., *Clonorchis sinensis* or “Chinese liver fluke”) and are more common in Asian countries.

Watch Out

Brown stones form from Bacteria, while Black stones form from the Blood.

What Are the Different Manifestations of Gallstone Disease?

Table 18.3

Condition	Mechanism
<i>Symptomatic cholelithiasis</i>	Transient obstruction of the cystic duct → visceral peritoneal stretch → RUQ pain
<i>Acute cholecystitis</i>	Persistent obstruction of the cystic duct → visceral peritoneal stretch → inflammation of the gallbladder → bacterial overgrowth → infection of the gallbladder → parietal peritoneum inflammation
<i>Cholelithiasis</i>	Obstruction of the common bile duct (CBD)
<i>Cholangitis</i>	Obstruction of the CBD → bacterial overgrowth → infection of the entire biliary tree → ascends into the liver
<i>Acute gallstone pancreatitis</i>	Obstruction of the CBD and pancreatic duct → pancreatic enzyme release
<i>Gallstone ileus</i>	Very large stone erodes into the duodenum → gallbladder-duodenal fistula → stone travels down the GI tract → small bowel obstruction (not ileus!)
<i>Mirizzi's syndrome</i>	Large gallstone impacted in the cystic duct → compresses the common hepatic duct

Watch Out

Gallstone ileus is a mechanical small bowel obstruction, typically as a result of the gallstone trapped at the terminal ileum near the ileocecal valve as this is the narrowest part of the gastrointestinal tract. Patients present with a tumbling obstruction with transient episodes of diffuse abdominal pain and nausea and air in the biliary tree (from the cholecystoduodenal fistula).

Work-Up

What Is the Next Step in the Work-Up? What Are the Specific Findings That Would Confirm the Diagnosis?

A RUQ ultrasound is the diagnostic test of choice. Gallstones appear as highly echogenic areas with acoustic shadows. The ultrasound should also note the thickness of the gallbladder wall (Figs. 18.1, 18.2, and 18.3) and whether there is any fluid surrounding the gallbladder. These two findings, gallbladder wall thickening (>4 mm) and pericholecystic fluid, are diagnostic for acute cholecystitis. The ultrasound should make note of the diameter of the CBD as well as whether a stone is visualized within it.

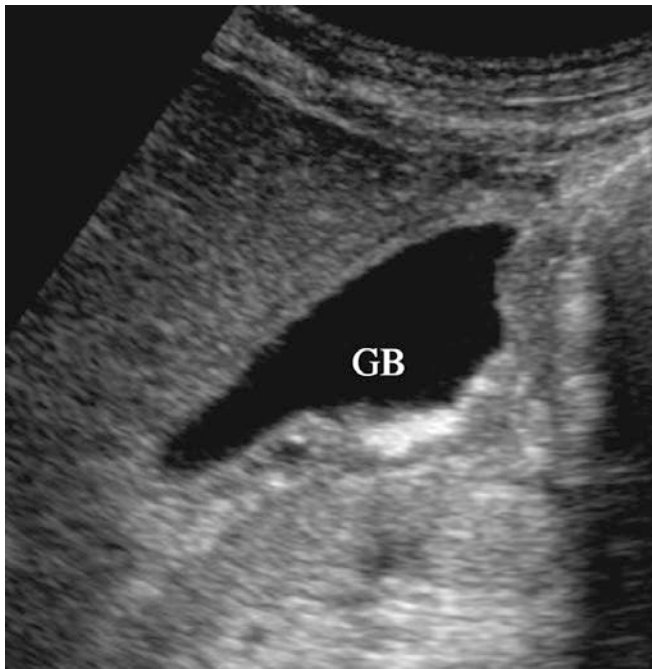
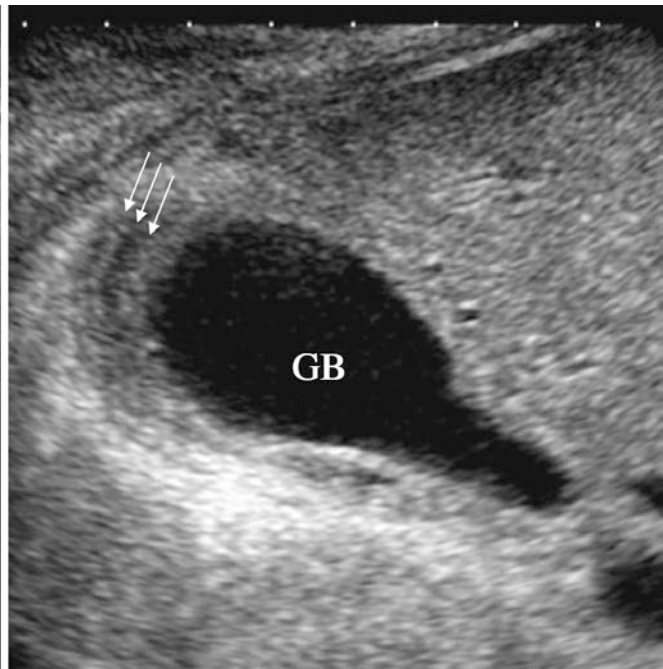


Fig. 18.1 Thickened gallbladder wall on ultrasound. (From Kimura Y et al. TG13 current terminology, etiology, and epidemiology of acute cholangitis and cholecystitis. J Hepatobiliary Pancreat Sci. 2013;20:12.



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Fig. 18.2 RUQ abdominal ultrasound of a normal thin-walled gallbladder



Fig. 18.3 RUQ ultrasound showing thickened, edematous gallbladder wall consistent with acute cholecystitis

Watch Out

Most gallstones are radiolucent, so a CT scan of the abdomen may be negative. Be sure to still order a RUQ ultrasound if biliary disease is suspected since ultrasonography has higher sensitivity in detecting gallstones.

What Is a Sonographic Murphy's Sign?

Instead of using the examiner's hand, direct pressure to the RUQ is applied by the ultrasound probe, under ultrasound guidance, while the patient inspires. The pain causes cessation of inspiration. This is thought to be more specific than a clinical Murphy's sign because the gallbladder can be directly visualized as coming in contact with the abdominal wall.

What Is the Normal CBD Diameter, and What Is the Implication of a Dilated CBD?

A normal CBD ranges from 4–5 mm. The normal diameter increases slightly with age (approximately 1 mm per decade after age 40). In most patients a CBD >6 mm is considered abnormally dilated. This suggests obstruction from either a gallstone or a tumor.

How Accurate Is Ultrasonography in Detecting Gallstones Within the Gallbladder? Within the CBD?

Ultrasound is very sensitive (95%) and specific (97%) for gallstones (even as small as 1–2 mm) within the gallbladder. Conversely, it is very poor for detecting gallstones within the CBD (sensitivity of about 50%) as bowel gas interferes with the ultrasound waves.

What If the Ultrasound Demonstrates Gas Bubbles in the Gallbladder Wall?

This would be concerning for emphysematous cholecystitis, an infection due to gas-forming organisms. This diagnosis is common in older men, often with diabetes mellitus. Bile cultures will often grow *Clostridium* or *E. coli*. This can progress to gallbladder perforation, intra-abdominal abscess, sepsis, and death if cholecystectomy is not performed emergently along with administration of broad-spectrum antibiotics (that must also cover *Clostridia*).

Watch Out

Do not confuse pneumobilia (Fig. 18.4) which is air in the biliary tree secondary to recent biliary instrumentation or gallstone ileus (due to a fistula between the gallbladder and duodenum) with air in the gallbladder wall (due to gas-forming bacteria) seen in patients with emphysematous cholecystitis (Figs. 18.5 and 18.6).

Why Should Liver Tests, Amylase, and Lipase Always Be Sent in the Presence of RUQ and Epigastric Pain? What Is the Significance of Abnormalities?

A liver panel should include total and direct bilirubin, aspartate (AST) and alanine (ALT) aminotransferase, alkaline phosphatase (AP), and gamma-glutamyl transferase (GGT). In a patient who only had symptomatic cholelithiasis, all of these should be normal. Mild elevations can be seen in acute cholecystitis. Significantly elevated AP and GGT out of proportion to AST and ALT suggest cholestasis or biliary obstruction and are often related to choledocholithiasis. In contrast,



Fig. 18.4 Gallstone ileus. (From Liau et al. A case of gallstone-induced small bowel necrosis masquerading as clinical appendicitis. *Clin J Gastroenterol.* 2009;2:239. Reprinted with permission)

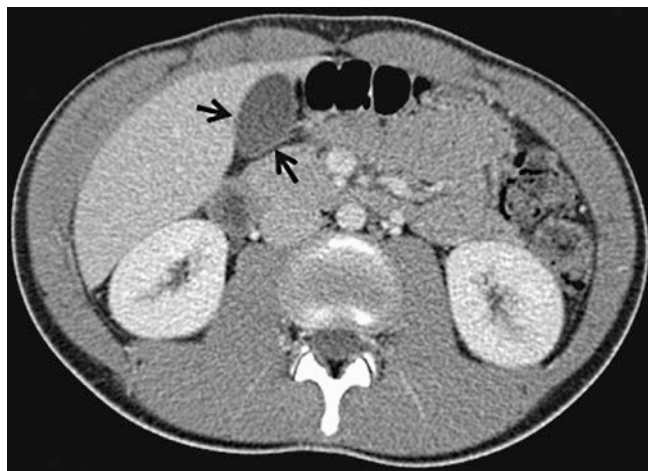


Fig. 18.5 Axial CT of a normal thin-walled gallbladder

marked elevations in AST or ALT, out of proportion to the AP and GGT, indicate hepatocellular damage and a primary hepatic pathology such as viral or alcoholic hepatitis or any other condition in which hepatocyte necrosis is occurring.

Is Amylase or Lipase Better to Rule Out Pancreatitis?

Lipase has a much higher sensitivity for pancreatitis than amylase. Lipase is the test of choice to rule out pancreatitis.

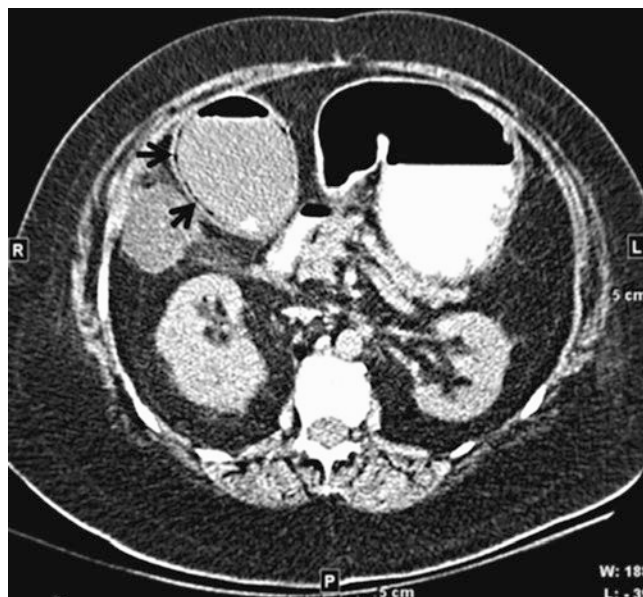


Fig. 18.6 Axial CT showing air in the gallbladder wall, known as emphysematous cholecystitis

Watch Out

Liver tests such as AST, ALT, and AP do not actually reflect the synthetic function of the liver (thus the term “liver function test” is a misnomer). Better tests of the liver’s synthetic function include serum albumin, prothrombin time (PT), and international normalized ratio (INR), as the liver synthesizes albumin and clotting factors. Even these tests, however, can be affected by extrahepatic disease.

What If Acute Cholecystitis Is Suspected but the Ultrasound Does Not Demonstrate Gallstones?

One possible explanation is the rare false-negative ultrasound (<5%). This may occur if gallstones are very small (≤ 1 mm) or if there are very few gallstones. Another possibility is acalculous cholecystitis. If abdominal ultrasound is negative for gallstones, a hepatobiliary iminodiacetic acid (HIDA) scan is done. In this test, radiolabeled hepatic iminodiacetic acid is given intravenously, and then imaging is performed. This compound is absorbed by hepatocytes and then excreted into bile and seen within 30–60 min in the gallbladder, bile ducts, and small bowel in a normal patient. If the cystic duct is obstructed, as in acute cholecystitis, no uptake will be seen within the gallbladder, and the HIDA scan is considered positive. This test has a sensitivity of 97% and a specificity of 90%.

Can You Develop Acute Cholecystitis Without Gallstones?

Yes, acalculous cholecystitis (cholecystitis in the absence of gallstones) can occur, though very rare. This typically occurs

in critically ill patients who are hospitalized for other reasons and have fasted for prolonged periods and are receiving total peripheral nutrition. It is thought to be a combination of bile stasis and gallbladder ischemia from hypoperfusion. Ultrasound will typically demonstrate a thickened gallbladder wall or pericholecystic fluid without stones. If ultrasound is completely negative, a HIDA scan is obtained. Treatment includes IV antibiotics and emergent intervention. If the patient is stable, emergent cholecystectomy is performed. If the patient is unstable, percutaneous cholecystostomy (tube to drain the gallbladder) is performed followed by cholecystectomy once the patient is medically stable.

Watch Out

Common settings for acalculous cholecystitis include critically ill patients on ventilators and post cardiopulmonary bypass. The low-flow state leads to gallbladder ischemia, stasis, and inflammation.

Management

What Is the Difference Between an Urgent and Emergent Case?

An urgent case can be booked during the next available operating room (OR) time slot (6–24 hours), while an emergent case requires a patient to be rushed to the OR immediately.

What Is the Next Step in the Management of a Patient with an Ultrasound Demonstrating Gallstones, Pericholecystic Fluid, Gallbladder Wall Thickening of 5 mm, and a Positive Sonographic Murphy's Sign?

Patients with acute cholecystitis should be admitted to the hospital, made NPO, and given IV fluids and IV antibiotics with gram-negative and anaerobic coverage. Historically, patients with acute cholecystitis were admitted for a “cool down” period with medical management prior to undergoing cholecystectomy. However, the consensus now is that early laparoscopic cholecystectomy (provided the patient is not medically considered high risk) within 48–72 hours of presentation leads to fewer surgical complications and decreases length of stay.

What Is the Ideal Choice of Antibiotics?

Antibiotics must be tailored to the most likely organisms (enteric). Second-generation cephalosporins (e.g., cefoxitin) are considered first line. An alternative would be broad-spectrum penicillin/β-lactamase inhibitors such as piperacillin/tazobactam or ampicillin/sulbactam. In severe cases, third- and fourth-generation cephalosporins may be used.

What If Gallstones Are Discovered Incidentally? Do They Require a Cholecystectomy?

There is no benefit for cholecystectomy for asymptomatic gallstones. Up to 20% of Americans >60 years old have asymptomatic gallstones.

How Should Symptomatic Cholelithiasis Be Managed?

A patient with symptomatic cholelithiasis should undergo cholecystectomy on an elective basis. For patients with symptomatic cholelithiasis and that are poor surgical candidates, medical management with ursodeoxycholic acid is a viable option.

Postoperative

What Is a Major Complication of Laparoscopic Cholecystectomy That Is More Common in the Setting of Acute Cholecystitis?

CBD injury is one of the most feared complications of laparoscopic cholecystectomy. There is a higher risk of CBD injury in men and during surgery for acute cholecystitis as compared to symptomatic cholelithiasis. The injury is often made when the CBD is mistaken for the cystic duct, and thus the CBD is inadvertently divided. Bile duct injuries can lead to strictures, resulting in recurrent cholangitis and eventually cirrhosis and liver failure requiring transplantation.

What Is the Differential Diagnosis and Work-Up for Abdominal Pain That Develops Soon After Cholecystectomy?

The work-up for patients who present postoperatively with abdominal pain, bloating, and anorexia soon after cholecystectomy is demonstrated in [Fig. 18.7](#). Work-up includes liver function tests, an ultrasound, and/or a CT scan of the abdomen/pelvis to look for an intraperitoneal fluid collection. Such a fluid collection after cholecystectomy represents either blood (from a liver injury or cystic artery bleed) or bile leaking (termed a biloma, emanating from either a liver injury, cystic duct stump leak, or common bile duct injury). If a fluid collection is found, it should be percutaneously drained. If drainage continues, a HIDA scan is obtained to rule out a bile leak and/or a bile duct injury. A cystic duct stump leak is treated with endoscopic-retrograde cholangiopancreatography (ERCP) and stenting of the sphincter of Oddi. However, a CBD injury may require hepaticojejunostomy.

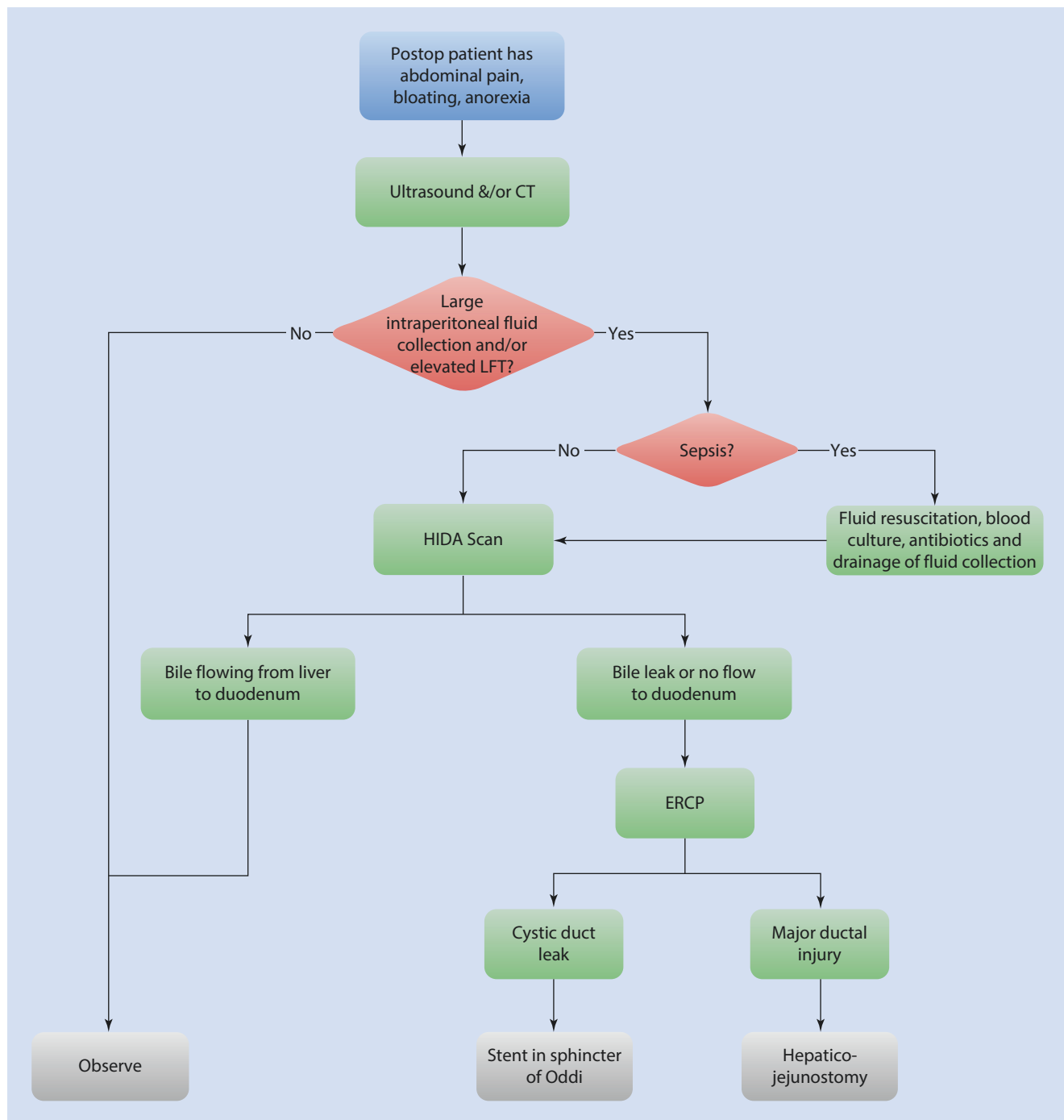


Fig. 18.7 Work-up for delayed recognition of CBD injuries

What Is the Differential Diagnosis If the Patient Develops RUQ Pain Several Weeks or Months After Cholecystectomy?

Recurrent RUQ/epigastric pain that develops weeks or months after cholecystectomy is referred to as postcholecystectomy syndrome (PCS) and is detailed in Table 18.4. Work-up should begin with a complete blood count and liver function tests, followed by a RUQ ultrasound. If ongoing pathology in the biliary tree is suspected, an ERCP would be the next test of choice.

What Is Sphincter of Oddi Dysfunction (SOD)?

SOD is a rare functional biliary disorder due to either stenosis or dyskinesia of the sphincter of Oddi. It is most commonly recognized in patients who have recently undergone laparoscopic cholecystectomy and continue to have episodic RUQ pain, particularly when they receive opioids (e.g., morphine). Ultrasonography of SOD in patients with intact gallbladders generally shows moderate distension of the gallbladder and

Table 18.4 Postcholecystectomy Syndrome (PCS)

Etiology	Features
<i>Residual stone in CBD</i>	This can lead to pancreatitis, cholangitis, or biliary obstruction
<i>Gallstone in cystic duct stump</i>	Patients with anatomically longer cystic ducts are at risk for retained gallstones
<i>Sphincter of Oddi dysfunction</i>	Increased pressure at the sphincter of Oddi can lead to impaired function of the biliary tree
<i>Other</i>	Gastritis, peptic ulcer disease

common bile duct. Mildly elevated liver enzymes corresponding with episodic pain are also seen. Further management may include sphincter of Oddi manometry or endoscopic sphincterotomy. Of note, SOD has also been implicated in recurrent acute pancreatitis.

Area of Controversy

When Should Acute Cholecystitis Be Managed Nonoperatively?

Critically ill patients with acute cholecystitis may have an unacceptable amount of operative risk. In a high-risk surgical patient, occasionally acute cholecystitis can be managed initially with antibiotics alone. Some will resolve with this approach. If the patient does not improve, and is a prohibitive operative risk, a percutaneously placed cholecystostomy tube is used to decompress the infected gallbladder. This approach is often used for acute acalculous cholecystitis. This can represent a permanent solution to acute cholecystitis or can be followed with interval cholecystectomy depending on the patient's clinical status.

Summary of Essentials

History

- RUQ pain in obese, multiparous female

Physical Exam

- Murphy's sign for acute cholecystitis

Pathology/Pathophysiology

- Acute cholecystitis triggered by persistent cystic duct obstruction by gallstone

Diagnosis

- RUQ US: gallstones, pericholecystic fluid, thickened gallbladder wall, and sonographic Murphy's sign.
- HIDA scan if RUQ ultrasound is nondiagnostic.
- KUB not helpful: only 10% of gallstones are radiopaque.
- Ninety percent of acute cholecystitis is superimposed on chronic.

Management

- Asymptomatic gallstones: cholecystectomy not indicated
- Symptomatic cholelithiasis (biliary colic): elective lap cholecystectomy
- Acute cholecystitis: prompt (within 48–72 hours) lap cholecystectomy
- Acute acalculous cholecystitis: percutaneous cholecystostomy tube if critically ill
- Emphysematous cholecystitis: emergent cholecystectomy
- Gallstone ileus: remove large impacted gallstone from terminal ileum (leave gallbladder alone)

Postoperative

- If a patient presents within the first week after cholecystectomy with abdominal pain, distention, and anorexia, consider a biloma (cystic duct stump leak, CBD injury).
- Cystic duct stump leak readily treated with ERCP and stenting of the sphincter of Oddi.
- CBD injury may require hepaticojejunostomy.

Additional Important Facts

- Calcified gallbladder (porcelain) (■ Fig. 18.8): increased risk of malignancy (especially if scattered calcification), perform cholecystectomy
- Choledochal cysts are congenital dilations of the biliary tree; prone to cholangitis, risk of associated malignancy, need to excise (if intrahepatic ducts are involved (Caroli's disease) may need liver transplantation)



■ **Fig. 18.8** Porcelain gallbladder on coronal CT. (From Amorosa JK, et al. Gastrointestinal radiology. In: Pitchumoni C, Dharmarajan T, editors. Geriatric gastroenterology. New York: Springer; 2012. Reprinted with permission)

- Gallbladder cancer: associated with gallstones (always check final path)
- Gallbladder polyps: >1 cm suspicious for cancer; >2 cm high likelihood of cancer

Suggested Reading

- Falor AE, Zobel M, Kaji A, Neville A, de Virgilio C. Admission variables predictive of gangrenous cholecystitis. *Am Surg.* 2012;78(10):1075–8.
- Gutt CN, Encke J, Königer J, Harnoss JC, Weigand K, Kipfmüller K, Büchler MW. Acute cholecystitis: early versus delayed cholecystectomy, a multicenter randomized trial (ACDC study, NCT00447304). *Ann Surg.* 2013;258(3):385–93.



Right Upper Quadrant Pain, Fever, Nausea, and Vomiting

*Manan P. Shah, Matthew Y. C. Lin, Paul N. Frank,
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Case Study

A 40-year-old female presents with a 24-hour history of right upper quadrant (RUQ) and epigastric pain associated with nausea and vomiting. She has had similar pain in the past, particularly after eating greasy foods. According to her family, over the last few hours, the patient has become slightly confused. She has also noticed dark urine today. Past medical history is

negative. Physical examination reveals a temperature of 39.1 °C, a heart rate of 110 beats/min, respiratory rate of 16/min, and a blood pressure of 90/60 mmHg. Her RUQ is moderately tender to deep palpation. She has slight scleral icterus. The remainder of her abdominal exam is negative. Laboratory examination is significant for a white blood count of $15 \times 10^3/\mu\text{L}$ (normal

$4.1\text{--}10.9 \times 10^3/\mu\text{L}$), a total bilirubin of 4.0 mg/dl (0.1–1.2 mg/dl), alkaline phosphatase (AP) of 350 μL (33–131 μL), aspartate aminotransferase (AST) of 44 μL (5–35 μL), alanine aminotransferase (ALT) of 65 μL (7–56 μL), gamma-glutamyl transpeptidase (GGT) of 330 μL (8–88 μL), and an amylase of 100 μL (30–110 μL). Urine is positive for bilirubin.

Diagnosis

What Is the Differential Diagnosis?

Table 19.1

Disease	Pathophysiology
Acute cholecystitis	Obstruction of cystic duct by gallstone → cholestasis and inflammation of the gallbladder
Choledocholithiasis	Obstruction of common bile duct (CBD) by gallstone
Gallstone pancreatitis	Obstruction of the CBD distal to pancreatic duct, often at the ampulla of Vater → inflammation of pancreas, cholestasis
Cholangitis	Obstruction of the CBD → ascending bacterial infection of the biliary system, cholestasis
Sphincter of Oddi dysfunction	Dyskinesia or stenosis of the sphincter of Oddi leading to cholestasis, worsened with opioids
Mirizzi's syndrome	Large stone lodged in the neck of the gallbladder causing external compression of the common hepatic duct
Viral hepatitis	Viral infection of the liver; can be acute or chronic
Pyogenic (bacterial) liver abscess	Hematogenous infection (e.g., endocarditis, IV drugs) or local spread from biliary disease
Amoebic liver abscess	<i>Entamoeba histolytica</i> enters portal system from the colon via ulceration

What Is the Diagnosis for This Patient?

The most likely diagnosis in a patient with a 1-day history of RUQ pain worsened with greasy foods, nausea, altered mental status, jaundice, and fever is acute cholangitis secondary

to gallstone impaction. Additionally, she has leukocytosis, hypotension, hyperbilirubinemia, and elevated alkaline phosphatase (AP), all of which are consistent with acute cholangitis.

What Are the Diagnostic Criteria for Cholangitis?

The Tokyo guidelines have been proposed as diagnostic criteria for acute cholangitis. Acute cholangitis should be suspected in patients who show evidence of systemic inflammation (fever, chills, leukocytosis) and cholestasis (jaundice or elevated bilirubin). The diagnosis is confirmed by imaging that shows biliary dilation or an etiology of biliary obstruction (e.g., stone, stricture, or stent).

History and Physical

What Are the Causes of Obstructive Jaundice That Lead to Cholangitis?

Gallstones are the most common cause. Other causes of obstruction include bile duct strictures, parasites (such as *Ascaris lumbricoides* and Chinese liver fluke, *Clonorchis sinensis*), instrumentation of the biliary system (such as during endoscopic retrograde cholangiopancreatography [ERCP]), and indwelling biliary stents.

Why Does the Patient Have Dark Urine but Not Pale Stools?

Pale or acholic stools are a result of prolonged biliary obstruction, so this would not be expected in patients with acute gallstone cholangitis. However, acute biliary obstruction can lead to an increased level of conjugated bilirubinemia which may be excreted by the kidneys making the urine appear dark ("Coca-Cola-colored urine").

At What Level of Bilirubin Will Jaundice First Be Visible?

Jaundice may be visible at total bilirubin level >2.5 mg/dl. Normal total bilirubin level is up to 1.0 mg/dl.

Where Do You Look for Jaundice?

Jaundice will manifest first in the sclerae of the eyes and under the tongue as the blood vessels there are more superficial. It will then descend down toward the chest, abdomen, and legs.

What Is Charcot's Triad?

Charcot's triad consists of fever, right upper quadrant pain, and jaundice. This cluster of symptoms is classically associated with cholangitis.

What Percent of Patients with Cholangitis Have All Three of the Triad?

This presentation is found in only about 40–50% of patients with cholangitis. Thus, Charcot's triad is not very sensitive. Jaundice is not always clinically obvious.

What Is Reynold's Pentad? What Percent of Patients with Cholangitis Have All Components?

Reynold's pentad implies cholangitis with septic shock. It includes Charcot's triad plus hypotension and mental status changes. It is present in the minority of patients with cholangitis (5%). An altered mental status is indicative of severe disease and associated with a poor prognosis.

Watch Out

Elderly patients with cholangitis may remain asymptomatic until they develop septic shock.

Pathophysiology

Why Are Gallstones the Most Common Cause of Obstructive Jaundice with Cholangitis?

To get cholangitis, one needs a combination of biliary obstruction and bacteria in the bile. As the stone passes from the gallbladder to the biliary tree, it may get trapped at the narrowest portion, the distal common bile duct. The obstruction

raises biliary pressure which causes increased permeability of the small biliary ducts, allowing bacteria from the portal circulation into the biliary tract. The biliary stasis also allows for retrograde travel of bacteria from the duodenum up the biliary tract. Finally, recent evidence suggests that biofilms on the surface of gallstones harbor bacteria.

Watch Out

Asymptomatic carriers of *Salmonella typhi* harbor the bacteria in the gallbladder (Typhoid Mary, the first person identified as a carrier in the USA, refused to have a cholecystectomy).

What Are Potential Consequences of Unrecognized Acute Cholangitis?

Severe untreated cholangitis can give rise to severe sepsis, hepatic microabscesses, and death. If the patient with acute cholangitis develops hepatic microabscesses, AST and ALT will markedly increase as a result of direct hepatocyte damage and necrosis.

Is Clinical Jaundice Always a Sign of Biliary Disease?

Not always. Gilbert syndrome is the most common inherited disorder of bilirubin glucuronidation affecting 5% of the population. These patients can present with clinical jaundice shortly after stressors such as intense sports activities or even after surgery.

Watch Out

Patients presenting with postoperative jaundice (unconjugated hyperbilirubinemia) shortly after a relatively minor surgery (e.g., laparoscopic appendectomy, skin surgery) may have Gilbert syndrome.

Workup

Why Is it Important to Distinguish Between Hepatic and Posthepatic Causes of Jaundice? How Do You Utilize the LFTs to Do So?

Hepatic causes of jaundice (such as hepatocellular injury from hepatitis) are usually nonsurgical problems, whereas posthepatic causes (such as biliary obstruction from acute cholangitis) are typically surgical. Distinguishing between the two is not always straightforward. Both will have some degree of elevation in total bilirubin, aspartate aminotransferase (AST), alanine aminotransferase (ALT), gamma-glutamyl

transpeptidase (GGT), and alkaline phosphatase (ALP). AST and ALT are enzymes within the liver cells (though AST is also found in the muscle and other cells). With hepatocellular injury, these enzymes are released and can sometimes reach into the thousands, rising out of proportion to the AP. Such a disproportionate rise in the transaminases is indicative of hepatocellular damage, as seen in acute viral hepatitis, ischemic or traumatic liver injury, or toxic insult. AP is present in the cells that line the bile ducts. A marked rise in AP, out of proportion to the AST and ALT, is therefore more indicative of posthepatic (biliary obstruction) pathology such as choledocholithiasis or cholangitis. Since AP levels increase with many other diseases (such as bone pathology), a concomitant and proportionate rise in GGT is helpful, as it is more specific for liver disease.

What Imaging Is the Diagnostic Test of Choice? Does the Test Provide Direct or Indirect Evidence for the Diagnosis?

The first-line diagnostic test is RUQ ultrasound (US). RUQ US is excellent in terms of visualizing gallstones within the gallbladder and in demonstrating dilation of the common bile duct due to obstruction. However, US is poor at detecting stones within the common bile duct. Thus, RUQ ultrasound provides only indirect evidence (dilated common bile duct) for cholangitis.

Management

What Are the Most Important Immediate Management Steps Once a Patient Develops Fever and Leukocytosis?

Once a patient is diagnosed with a systemic response, several things should promptly occur (■ Fig. 19.1). First, the patient should receive targeted *aggressive intravenous fluid resuscitation* with normal saline or lactated Ringer's. Indwelling foley catheter should be considered in order to guide resuscitation. Intravenous fluid administration should be titrated such that the patient's mean arterial pressure is at least 65 mmHg, and the patient's urine output is at least 0.5 mL/kg/h. Second, *broad-spectrum empiric IV antibiotics* should be started within 1 hour.

What Is the Antibiotic Treatment for Acute Cholangitis?

In the case of suspected cholangitis, antibiotics should cover enteric organisms (Gram-negative rods, enterococcus, and anaerobes). Additionally, at least two sets of *blood cultures*

should be obtained, ideally before the administration of antibiotics, but only if this does not cause delay.

Does the Patient Need Admission to the ICU?

Yes. These patients may require invasive hemodynamic monitoring, vasopressor support (in the event of severe sepsis or septic shock, with norepinephrine being the first choice), and intravenous antibiotics.

Once the Patient Is Resuscitated, Antibiotics Started, and the Diagnosis Is Established, What Intervention Is Recommended? What Is the Goal of That Intervention?

The next step in treatment is to drain the infected bile, termed biliary decompression. This is best accomplished by ERCP. During ERCP, a scope is inserted through the mouth to the ampulla of Vater. The ampulla is cannulated, the stone can be extracted, the sphincter of Oddi is cut (sphincterotomy) to allow drainage of the bile into the duodenum, and a stent is often placed. If ERCP is unsuccessful, percutaneous transhepatic drainage (PTC) is the next choice. In this procedure, the bile is drained via a catheter inserted directly into the liver. If both of these options fail, the bile may need to be decompressed operatively by placing a drain (called a T-tube) directly into the common bile duct.

Following Successful ERCP, What Is the Next Management Step?

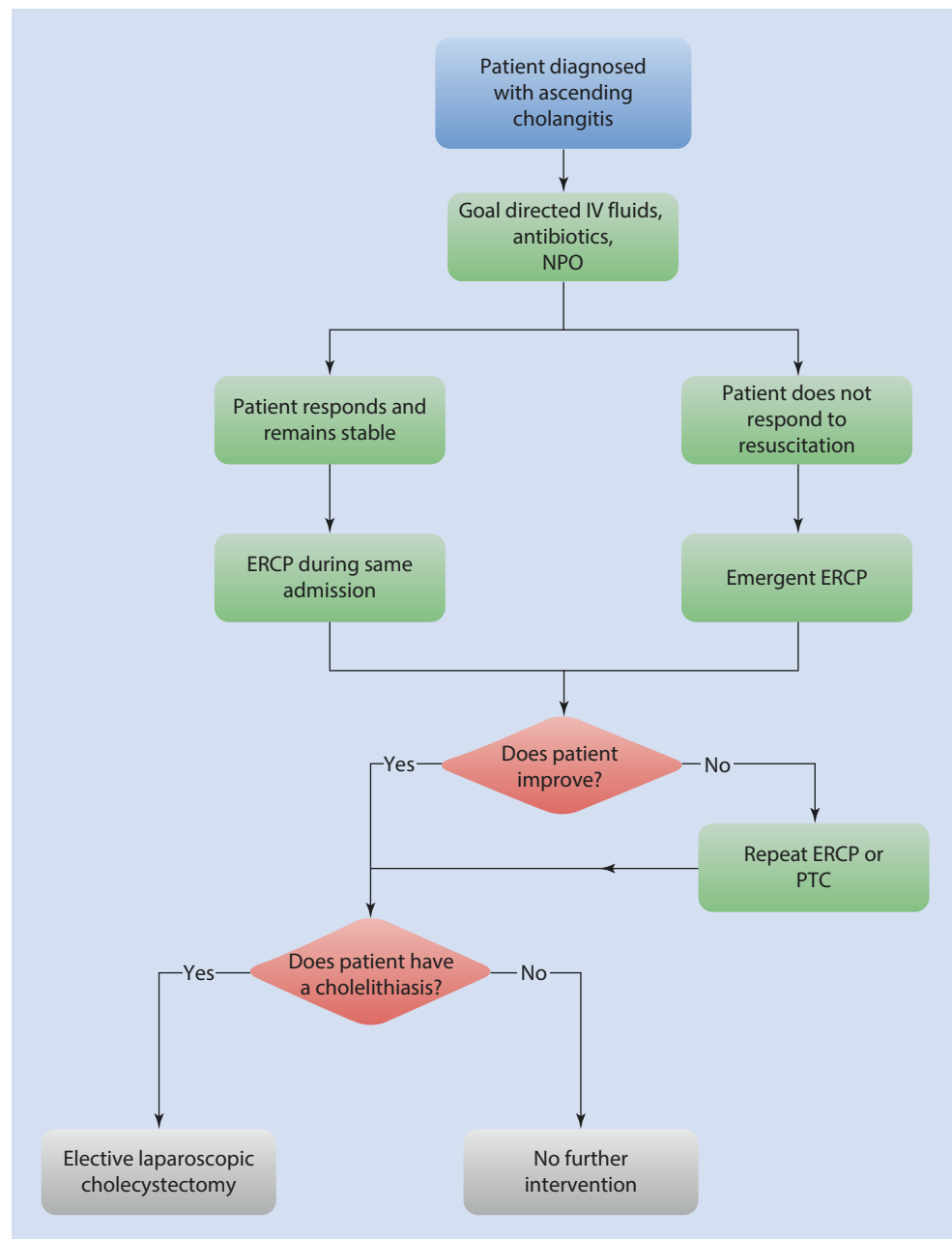
Once the patient's sepsis has completely resolved, they should undergo laparoscopic cholecystectomy (LC) to prevent future episodes (■ Fig. 19.1). Note, if the patient's cholangitis was not due to gallstones, then cholecystectomy is not indicated.

Areas Where You Can Get in Trouble

A History of Bloody Diarrhea in a Patient Who Presents with Cholangitis

A history of bloody diarrhea in a patient who presents with cholangitis is suggestive of inflammatory bowel disease (IBD) with primary sclerosing cholangitis (PSC). This occurs more commonly in patients with ulcerative colitis (vs. Crohn's) and is characterized by inflammation and fibrosis of the intrahepatic and extrahepatic bile ducts. Cholangiography shows multifocal areas of alternating stricturing and dilation of intrahepatic and/or extrahepatic bile ducts ("pearls on a string").

Fig. 19.1 Overall treatment algorithm



A Middle-Aged Woman with Pruritus, Fatigue, and Normal RUQ US

If a patient (generally a middle-aged woman) presents with pruritus, fatigue, mildly elevated AP, normal transaminases, and a normal RUQ US (no bile duct dilatation), then suspect a diagnosis of primary biliary cholangitis (PBC). Nowadays, patients are often diagnosed while asymptomatic with incidentally discovered elevation of ALP. PBC is a rare, autoimmune disorder of the bile ducts. Patients test positive for the anti-mitochondrial antibody (AMA). Management often includes ursodeoxycholic acid. Complications of PBC include cirrhosis, hepatobiliary cancers, malabsorption, and osteopenia.

Areas of Controversy

Is Cholecystectomy Necessary After Biliary Decompression?

The justification for cholecystectomy after cholangitis in a patient with gallstones is that it will prevent additional complications from gallstones, such as recurrent choledocholithiasis and cholangitis. Several randomized controlled trials have confirmed this by demonstrating significantly lower risk of biliary complications in patients who undergo elective laparoscopic cholecystectomy after bile duct clearance. Cholecystectomy should be done during the same admission.

Timing of ERCP with Severe Cholangitis: Emergently (in the Middle of the Night) or Urgently (the Next Morning)?

In patients with severe cholangitis, the initial management should focus on IV fluids, antibiotics, and, if needed, vaso-pressors (norepinephrine is the first-line agent). In general, a hemodynamically unstable and under-resuscitated patient should not be rushed to ERCP. However, if the patient fails to improve, ERCP should be performed expeditiously. Whether performing an emergent ERCP affects outcomes of severe cholangitis is debatable.

Summary of Essentials

History and Physical

- Charcot's triad.
- Reynold's pentad.
- Look for evidence of systemic inflammation (fever, tachycardia, leukocytosis).
- Elderly patients may be hypothermic and have leukopenia (are relatively immunosuppressed).

Etiology/Pathophysiology

- Biliary obstruction with ascending bacterial infection.
- Bacteria enter bile either via bloodstream from the portal vein or retrograde from the duodenum.
- Most commonly caused by gallstone obstruction of the distal CBD.
- Other causes: biliary stricture, cancer, parasites.
- Suppurative cholangitis: acute cholangitis complicated by septic shock.

Diagnosis

- Elevated white blood cell count
- AP and GGT elevated out of proportion to AST/ALT
- US: dilated CBD

Management

- Aggressive IV fluids, blood cultures, broad-spectrum antibiotics.
- Admit to ICU.
- Biliary decompression via ERCP.
- PTC if ERCP fails.
- Cholecystectomy after sepsis resolves to prevent further biliary complications.

Watch Out

- The diagnosis of acute cholangitis may be missed in the elderly and immunosuppressed (e.g., steroids).
- Think sclerosing cholangitis if also having symptoms of IBD.
- Suspect primary sclerosing cholangitis in a patient with ulcerative colitis.
- Suspect primary biliary cholangitis if there is pruritis, elevated AP, no duct dilatation, and positive AMA.

Suggested Reading

- Schwed A, Boggs M, Pham XD, Watanabe DM, et al. Association of admission laboratory values and the timing of endoscopic retrograde cholangiopancreatography with clinical outcomes in acute cholangitis. *JAMA Surg.* 2016;151(11):1039–45.
- Wada K, Takada T, Kwarada Y, et al. Diagnostic criteria and severity assessment of acute cholangitis: Tokyo Guidelines. *J Hepatobiliary Pancreat Surg.* 2007;14(1):52–8.



Severe Epigastric Pain with Nausea and Vomiting

Areg Grigorian, Matthew Y. C. Lin, and Christian de Virgilio

Case Study

A 41-year-old woman presents to the emergency department complaining of severe and continuous epigastric pain for the past 24-hours. The pain radiates straight through to her back. She has had progressive nausea with vomiting. The vomit is bile-stained and without blood. She has had similar but less severe episodes of abdominal pain in the past, usually after eating heavy meals, but they always resolved within a few hours. She is gravida two, para two, with last menses 2 weeks ago, and does not consume any

alcohol. On exam, she is afebrile, heart rate is 115 beats/min, blood pressure of 128/86 mmHg, and respiratory rate is 18/min. Her abdomen is not distended. She has no surgical scars on her abdomen and no obvious masses visible. She has no bruising around her umbilicus or along her flank. Bowel sounds are hypoactive. She has marked tenderness to palpation in her epigastrium, without guarding or rebound. The remainder of her abdomen is soft and non-tender to palpation. No masses or

organomegaly are appreciated. Laboratory examination reveals a white blood cell count of 17.2×10^3 cells/ μ L (normal 4.1– 10.9×10^3 cells/uL), amylase of 1545 u/L (30–110 u/L), lipase of 1134 u/L (7–60 u/L), ALT of 245 u/L (7–56 u/L), AST of 263 u/L (5–35 u/L), serum glucose of 156 mg/dl (65–110 mg/dL), and LDH 180 u/L (0–250 u/L). An abdominal series demonstrates gas throughout the small and large bowel and a focal dilated loop of proximal small bowel without air fluid levels. There is no free air under the diaphragm.

Diagnosis

What Is the Differential Diagnosis for Epigastric Abdominal Pain?

Table 20.1

Condition	History and physical
<i>Gastroenteritis</i>	Nausea, extensive vomiting, diarrhea, myalgia, fever, mild abdominal tenderness
<i>Acute gastritis</i>	Burning/gnawing epigastric pain, NSAID use, mild abdominal tenderness
<i>Acute cholecystitis</i>	Right upper quadrant/epigastric pain radiating to around the right back, nausea, vomiting, fever, <i>Murphy's sign</i>
<i>Peptic ulcer disease (PUD)</i>	Intermittent burning epigastric pain that is better (duodenal ulcer) or worse (gastric ulcer) with food intake, nausea, <i>Helicobacter pylori</i> infection, NSAID use, steroids
<i>Perforated ulcer</i>	Initial epigastric pain, followed by diffuse tenderness, abdominal rigidity, rebound tenderness
<i>Pancreatitis</i>	Epigastric pain radiating to the back, nausea, vomiting, anorexia, fever, tachycardia, cholelithiasis, alcohol abuse
<i>Appendicitis</i>	Periumbilical pain migrating toward the right lower quadrant (<i>McBurney's point</i>), associated with nausea, vomiting, anorexia, fever, Rovsing's sign, psoas sign
<i>Small bowel obstruction</i>	<i>Adhesions</i> , hernia, neoplasms, dilated loops of bowel with air fluid levels, absence of distal colonic gas on plain radiograph
<i>Mesenteric ischemia</i>	"Severe abdominal pain out of proportion to physical exam," nausea, most often cardiac embolus to superior mesenteric artery from atrial fibrillation, bloody diarrhea in severe cases
<i>Ruptured AAA</i>	Severe abdominal/back/left flank pain, pulsatile abdominal mass, hypotension, elderly male smoker
<i>Referred pain from myocardial infarction</i>	Atypical presentation more common in women and diabetics, cardiovascular disease, obesity, hypercholesterolemia

NSAID nonsteroidal anti-inflammatory drugs

What Is the Diagnosis for This Patient?

Acute pancreatitis, most likely secondary to cholelithiasis. This patient has the classic presentation which consists of epigastric abdominal pain radiating straight through to the back with nausea and vomiting. She has had prior episodes of pain, which have resolved within a few hours, after eating heavy meals, which is characteristic of symptomatic gallstones. Since the vast majority of pancreatitis cases are due to gallstones or alcohol use and this patient does not consume alcohol, we can

conclude that her symptoms are most likely related to gallstones. Finally, the amylase and lipase are elevated.

How Do You Diagnose Acute Pancreatitis?

Acute pancreatitis is considered a clinical diagnosis. The Atlanta criteria were created for the diagnosis of acute pancreatitis. They require two of the following three:

1. Sudden, severe, persistent epigastric pain radiating to the back

2. Elevated lipase or amylase to three times greater than the upper limit of normal
3. Characteristic findings of acute pancreatitis on imaging (i.e., enlarged pancreas, sentinel loops [dilated small bowel], colon cutoff sign, etc.)

History and Physical

What Nonsurgical Conditions Can Mimic an Acute Abdomen?

Gastroenteritis, acute adrenal insufficiency, sickle cell crisis, diabetic ketoacidosis, acute porphyria, pelvic inflammatory disease, kidney stones, and pyelonephritis.

What Is the Significance of Bruising Around the Umbilicus, Flank, and Inguinal Ligament?

They are all signs of retroperitoneal hemorrhage in association with acute hemorrhagic pancreatitis where methemalbumin formed from digested blood tracks subcutaneously to different parts of the abdominal wall. *Grey Turner's sign* refers to a blue-black discoloration in the flanks. *Cullen's sign* is a blue-red discoloration at the umbilicus, and *Fox's sign* is bruising over the inguinal ligament.

Watch Out

Only about 10% of gallstones are radiopaque (visible on plain radiographs) versus 90% of kidney stones. An abdominal ultrasound is the first step in the evaluation for gallstones.

What Are the Signs, Symptoms, and Findings of Acute Pancreatitis?

Epigastric pain radiating to the back, worsened with food, nausea/vomiting (90% of cases), anorexia, or decreased oral intake. Physical exam frequently reveals fever, tachycardia, epigastric tenderness with localized guarding, and hypoactive bowel sounds secondary to reactive ileus.

What Structures Are in the Retroperitoneum?

One can remember these structures with the following mnemonic, "SAD PUCKER": suprarenal (adrenal) glands, aorta/IVC, duodenum (2nd and 3rd part), pancreas (except tail), ureters, colon (ascending and descending), kidneys, esophagus, and rectum.

Pathophysiology

What Is the Pathophysiology of Pancreatitis?

It initially occurs as a result of inappropriate activation of pancreatic enzymes leading to peripancreatic inflammation. Intraparenchymal extravasation of enzymes causes autodigestion of pancreatic parenchyma but primarily damages the peripancreatic tissues and vasculature. The inflammatory response is out of proportion to the insult and, with time, potentiates further damage leading to fluid sequestration, fat necrosis, vasculitis, and hemorrhage.

What Are the Etiologies for Pancreatitis?

- "GET SMASHED" will help you remember the causes of acute pancreatitis
 - G – gallstones (40%)
 - E – ethanol (30%)
 - T – tumors
 - S – scorpion stings
 - M – mycoplasma or mumps
 - A – autoimmune (Lupus or polyarteritis nodosa)
 - S – surgery or trauma
 - H – hyperlipidemia/hypercalcemia
 - E – ERCP or embolic/ischemic
 - D – drugs or toxins

Watch Out

The 4 "F's" for gallbladder disease are female, fat, forty, and fertile. Almost 40% of acute pancreatitis cases are caused by gallstones. However, only about 3–7% of patients with gallstones develop acute pancreatitis.

What Medications Can Cause Pancreatitis?

Table 20.2

Disease treated	Medications
Cardiovascular disease	Furosemide, thiazides
Inflammatory bowel disease	Sulfasalazine, 5-ASA
Immunosuppression	Azathioprine
Seizures	Valproic acid
Diabetes	Exenatide
Human immunodeficiency virus (HIV)	Didanosine, pentamidine

How Do Gallstones Cause Acute Pancreatitis?

The most prevailing theory is that as a gallstone passes from the gallbladder down into the common bile duct, it causes transient impaction at the ampulla which causes a sudden rise in pancreatic duct pressure.

In Patients with Gallstone Pancreatitis, How Often Does the Gallstone Remain Impacted in the Distal Common Duct?

The gallstones that cause pancreatitis are usually small, and as such, in the majority of cases, the stone remains impacted very briefly, only transiently obstructing the ampulla of Vater, and soon after passes into the duodenum. As such, persistence of a common bile duct (CBD) stone is uncommon, and therefore ERCP is not usually needed. This differs from gallstones that cause acute cholangitis, where the stones are usually large and usually need ERCP for removal.

What Are the Differences Between Acute and Chronic Pancreatitis?

Table 20.3

	Acute pancreatitis	Chronic pancreatitis
<i>Onset</i>	Severe and sudden	Recurrent episodes
<i>Etiology</i>	Gallstone (40%), alcohol (30%)	Alcohol (90%), anatomic defects (pancreas divisum), hereditary
<i>Presentation</i>	Epigastric pain radiating to the back, nausea, vomiting anorexia	Recurrent epigastric pain, weight loss, diabetes, steatorrhea
<i>Labs</i>	High amylase and lipase (more sensitive)	Low fecal elastase levels
<i>Radiology</i>	Dilated loops of bowel near pancreas (<i>sentinel loop</i>) on plain films	<i>Pancreatic calcifications</i> on plain films

Watch Out

The first stage of pancreatitis involves the premature activation of trypsin within the pancreatic acinar cells.

How Is the Severity of Pancreatitis Classified?

The severity of pancreatitis is classified as *mild*, *moderately severe*, and *severe*. Most patients (80–90%) have mild pancreatitis, which is characterized by the absence of multi-organ failure and local/systemic complications. It usually resolves in 2–5 days. Moderately severe includes transient organ failure lasting less than 48 hours and/or local or systemic complications. Severe pancreatitis is defined by organ failure that persists for more than 48 hours (worst prognosis).

What Organ Systems Can Be Affected by Acute Pancreatitis?

Cardiac, pulmonary, renal, and gastrointestinal.

How Is Organ Failure Defined?

Organ failure, as defined by the Atlanta Symposium, includes:

- Systolic blood pressure < 90 mmHg
- PaO₂ ≤ 60 mmHg
- Creatinine >2.0 mg/L after rehydration
- Gastrointestinal bleeding > 500 cc/24 hours
- Disseminated intravascular coagulation
- Metabolic disturbances (calcium < 7.5 mg/dl)

What Is the Mechanism of Hypotension in Pancreatitis?

Inflammation and cytokine storm cause endothelial injury and increased permeability in the peripancreatic vasculature, leading to fluid leaking into the retroperitoneal space (known as third spacing). The cytokine storm also causes massive vasodilation, which along with a shrunken intravascular volume can cause severe hypotension.

What Are the Main Pulmonary Complications of Acute Pancreatitis?

Pleural effusions (the majority on the left side) and acute respiratory distress syndrome (ARDS) (Fig. 20.1). These complications are thought to be due to cytokine-mediated vasodilation and pancreatic enzyme (e.g., phospholipase-A2)-mediated lung injury.



■ Fig. 20.1 Chest X-ray showing diffuse bilateral pulmonary infiltrates characteristic of ARDS

What Are the Different Histopathologic Types of Acute Pancreatitis? What Are the Important Differences?

The majority of patients (>80%) develop *acute interstitial edematous pancreatitis*, characterized by an enlargement of the pancreas due to inflammatory edema. Such patients have no inflammation or destruction of pancreatic cells. Less than 20% develop *necrotizing pancreatitis* characterized by necrotic pancreatic parenchyma which can lead to sepsis in over half the cases. *Hemorrhagic pancreatitis* is a type of necrotizing pancreatitis in which there is extensive bleeding into the pancreatic parenchyma and surrounding tissues. The type of pancreatitis is important because it determines both prognosis and management.

Prognosis

How Is the Severity of Pancreatitis Determined?

Severity is determined by using one of various scoring systems: Ranson (■ Fig. 20.2), APACHE II, or based on clinical evidence of local or systemic complications. Recently, the BISAP (bedside index of severity of acute pancreatitis) score has been found to be simpler than and as accurate as APACHE II. BISAP score is determined by adding one point for each of the following: BUN >25 mg/dL, impaired mental status, systemic inflammatory response syndrome (SIRS), age >60 years, and pleural effusion. The Ranson criteria are the most commonly used tool and include five admission variables and six criteria that are assessed after 48 hours. Use “GA (Georgia) LAW” to remember the parameters used in determining prognosis on admission. Use “CHOBBS” to remember the latter parameters. Each variable gets one point.

Admission
Glucose > 200 mg/dL
Age > 55 years
LDH > 350 IU/L
AST > 250 IU/L
WBC count > 16000 cells/mm

After 48 hours
Calcium < 8.0 mg/dL
Hematocrit decrease > 10%
Oxygen PaO ₂ < 60 mmHg
BUN increased by 5 mg/dL or more despite fluid resuscitation
Base deficit > 4 mEq/L
Sequestration of fluids > 6 L

Score 0–2	2% mortality
Score 3–4	15% mortality
Score 5–6	40% mortality
Score 7–8	100% mortality

■ Fig. 20.2 Ranson criteria

Watch Out

The degree of amylase and lipase elevation does *not* correlate with the severity of acute pancreatitis and should not be used to influence management (i.e., timing of surgery).

What Is the Main Drawback of Ranson Criteria?

It takes 48 hours to measure all variables, and by then, the majority of patients have already declared themselves as to whether their course will be mild or severe and whether they need to be in a monitored bed. In addition, the variables cannot be repeatedly measured on an hourly or daily basis to monitor improvement or deterioration.

Why Does One Get Hypocalcemia with Severe Pancreatitis?

With severe pancreatitis, free fatty acids are generated by the action of pancreatic lipase. The free fatty acids chelate calcium salts that are present in the pancreas, leading to saponification (the deposition of calcium soaps in the retroperitoneum).

What Is the Natural Disease Course of Acute Pancreatitis?

The majority of patients with acute pancreatitis recover in less than 5 days without any complications. Close to 20% of patients have a severe presentation with local or systemic complications (including organ failure).

What Is the Most Common Cause of Mortality in the First Week of Acute Pancreatitis? Beyond the First Week?

In the first week, death is most often due to multiorgan failure as a result of severe systemic inflammatory response. After the first week, mortality is most commonly due to sepsis secondary to pancreatic necrosis and peripancreatic abscesses (these most often develop in the third and fourth week of hospitalization). If a pancreatic abscess is not drained, mortality approaches 100%.

Workup

What Are the Most Important Laboratory Tests to Order when Suspecting Acute Pancreatitis?

Serum amylase, lipase, liver function tests (AST, ALT, AP), electrolytes, complete blood count, and a lipid panel. Amylase and lipase are typically elevated. Amylase levels tend to be much higher (often >1000 u/L) in patients with gallstone pancreatitis as compared to other etiologies. Similarly, elevated ALT greater than three times the upper limit of normal is highly suggestive of gallstone pancreatitis. However, close to 20% of patients will have normal LFTs. A lipid panel is important to rule out hyperlipidemic pancreatitis; usually due to hypertriglyceridemia (must be >1000 mg/dl).

Which Laboratory Test Is Most Specific for Acute Pancreatitis?

Lipase is most specific (and sensitive). Numerous other diseases can cause hyperamylasemia (■ Table 20.4).

Watch Out

In patients with hemorrhagic pancreatitis, the initial hematocrit is *not* a good indicator of blood loss. The hematocrit may take 1–2 days to equilibrate. In addition, if the patient is severely volume depleted, it may lead to hemoconcentration, giving a falsely elevated or normal hematocrit.

■ Table 20.4 Hyperamylasemia

Conditions	Specific diseases
<i>Pancreatic disease</i>	Pancreatitis, pancreatic pseudocyst, trauma, ERCP, pancreatic carcinoma, cystic fibrosis
<i>Salivary disease</i>	Parotitis, radiation, ductal obstruction
<i>Gastrointestinal disease</i>	Peptic ulcer disease, perforated bowel, mesenteric ischemia, appendicitis, cholecystitis, celiac disease
<i>Other</i>	Alcohol abuse, renal failure (amylase is renally cleared)

What Is the Diagnostic Imaging of Choice on Admission for Acute Pancreatitis?

Right upper quadrant ultrasound. Since the most common cause of acute pancreatitis is gallstones, this is the first etiology that should be ruled out.

What Are the Classic Abdominal X-Ray Findings in Acute Pancreatitis?

A sentinel loop (dilated loops of proximal small bowel in the left upper quadrant near the pancreas) and colon cutoff sign (distended proximal colon with abrupt collapse in the left upper quadrant at the splenic flexure). Both are due to local ileus (paralyzed, nonmotile bowel) as a result of the pancreatic inflammation.

Watch Out

The delayed development of an ileus in a patient with pancreatitis or following trauma may indicate retroperitoneal bleeding.

What Is the Classic Chest X-Ray Finding in Acute Pancreatitis? How Does This Finding Influence Prognosis?

A pleural effusion, classically on the left side. In patients with severe pancreatitis, nearly 85% have evidence of pleural effusion on admission. In contrast, only 15% of patients with mild pancreatitis have a pleural effusion on plain films upon admission. This finding is strongly associated with severe pancreatitis.

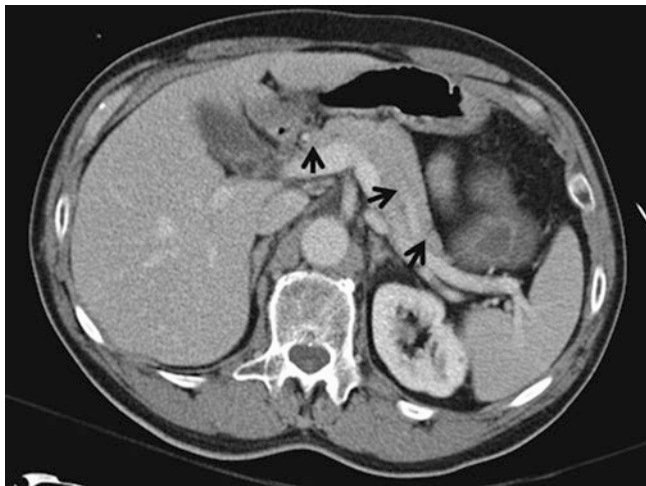
What Is the Role of Abdominal CT Scan on Admission?

CT scan should not be routinely ordered on admission, as it does not change management in the vast majority of cases. Though CT scan can help distinguish between mild and

severe pancreatitis, clinical criteria are equally useful in making this distinction. Severe pancreatitis can cause a diffuse peritonitis-like exam, so a CT is useful when the diagnosis is in doubt.

What Is the Role of Abdominal CT Scan During Subsequent Hospitalization?

If the patient is not clinically improving after several days of conservative management, CT scan is helpful as it may explain the lack of improvement (such as whether there is pancreatic necrosis). Beyond the first week, CT scan is helpful in the situation where a patient develops worsening abdominal pain, fever, and sepsis, as it may demonstrate a pseudocyst or a pancreatic abscess (these local complications do not manifest on admission) (■ Figs. 20.3, 20.4, and 20.5).



■ Fig. 20.3 Axial CT with a normal-appearing pancreas. (Black arrows: normal pancreas)



■ Fig. 20.4 Axial CT scan with peripancreatic fluid collections exhibiting thick irregular walls and marked fat stranding, consistent with abscesses



■ Fig. 20.5 Axial CT scan showing a thin-walled peripancreatic fluid collection consistent with pancreatic pseudocyst

What Is the Role of Urgent ERCP in Gallstone Pancreatitis?

It is rarely needed – only if there is a suspected concomitant acute cholangitis. ERCP itself may cause pancreatitis. If ERCP is necessary, indomethacin rectal suppository reduces risk of pancreatitis.

Management

What Is the Initial Treatment for Acute Pancreatitis?

Treatment is supportive, and patients are managed conservatively with vigorous intravenous fluid resuscitation, NPO, and analgesics. Routine nasogastric tube decompression is not recommended (only if there is ongoing vomiting). Similarly, routine use of antibiotics is not recommended. The majority of patients' symptoms resolve within 3–5 days with this management.

Watch Out

Although not applied clinically, some test questions prefer meperidine over morphine for pain control in acute pancreatitis because in theory, meperidine does not cause contraction of the sphincter of Oddi (whereas morphine does) and may allow for quicker resolution of symptoms. However, meperidine increases the risk of seizures.

What Is the Subsequent Management Plan? And How Does This Differ Between Gallstone and Alcoholic Pancreatitis?

If gallstones were found on presentation (and there is no history of alcohol abuse), a cholecystectomy should be performed during the same hospitalization because recurrent gallstone pancreatitis risk is high within 30 days. The tim-

ing of surgery depends on pancreatitis severity. Amylase and lipase levels should *not* influence timing of surgery. If alcohol is the etiology, counsel the patient on alcohol cessation, and provide referral for support groups.

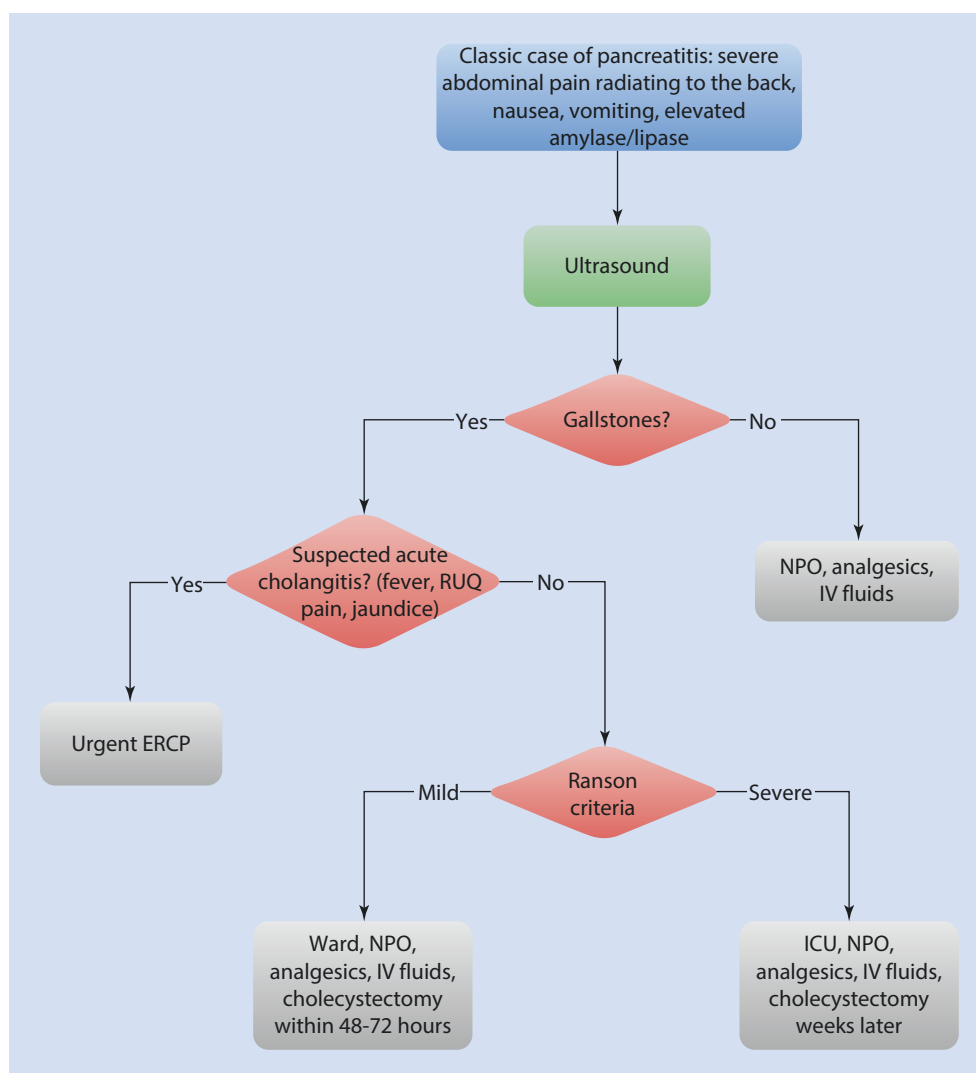
How Does the Severity of Acute Pancreatitis Affect Management?

Pancreatitis severity assists in triage to a ward (mild pancreatitis) or monitored step-down or ICU bed (moderately

severe or severe pancreatitis). If severe pancreatitis is predicted, it raises awareness to monitor the patient closely for local and/or systemic complications. For gallstone pancreatitis, it assists in determining timing of cholecystectomy: early (within 48–72 hours) for mild pancreatitis versus delayed (weeks later after complete resolution) for moderately severe or severe pancreatitis.

What Is the Management Algorithm for Acute Pancreatitis? ■ Fig. 20.6

■ Fig. 20.6 Management algorithm for acute pancreatitis. (Based on the practice guidelines from the American College of Gastroenterology)



Special Situations

What Should You Suspect if a Patient with Severe Acute Pancreatitis Develops a Fever and Leukocytosis 4 Weeks into the Hospitalization?

This presentation is concerning for a pancreatic abscess. The first step is to order a CT scan with contrast looking for necrotic tissue (i.e., areas that do not enhance) or a pancreatic abscess. If you find evidence of either, a CT or ultrasound-guided aspiration should be performed and sent for culture. If infection is present, antibiotics are administered. Infected pancreatic necrosis and pancreatic abscesses require surgical debridement using a step-up approach (sequential additional steps if needed): (1) percutaneous or endoscopic drainage, (2) video-assisted retroperitoneal debridement (VARD), and (3) open necrosectomy. These procedures are termed external drainage.

What Should You Suspect If a Patient with a Recent Hospitalization for Pancreatitis Comes in 6 Weeks Later with Vague Abdominal Pain, a Palpable Epigastric Mass, and Persistently Elevated Serum Amylase?

A pancreatic pseudocyst, a collection of pancreatic fluid surrounded by a wall without epithelium. It results from pancreatic injury such as pancreatitis or trauma, which essentially disrupts a pancreatic duct. The pancreatic enzymatic fluid that leaks out is contained by surrounding fibrotic tissue. Although this most commonly appears in patients with chronic pancreatitis, it can also occur in the weeks following resolution of an acute pancreatitis. Patients often present with vague abdominal pain, elevated serum amylase, and possibly a palpable epigastric mass. The diagnostic test of choice is a CT scan, and most can be managed conservatively. Predictors of failure for conservative management include pseudocysts larger than 6 cm or those that have persisted for more than 6 weeks. Treatment of a symptomatic, non-infected pseudocyst that fails to resolve is usually via *internal drainage*, by creating a connection between the cyst and the adjacent intestinal organ, usually the stomach (endoscopic cystogastrostomy). External drainage is not recommended as this may create a pancreatico-cutaneous fistula. A pseudocyst can erode into arteries, leading to a pseudoaneurysm and upper GI bleed (managed with angiographic embolization).

Watch Out

Pancreatic cysts in the absence of a history of pancreatitis should raise suspicion for a neoplasm; biopsy should be considered.

What Are the Complications from Chronic Pancreatitis?

Patients may develop *diabetes mellitus* secondary to the destruction of beta-islet insulin-producing cells in the pancreas caused by chronic inflammation. This type of diabetes is termed *type-3 diabetes* and is very difficult to treat, and most patients require insulin. Patients may also develop *steatorrhea* due to poor absorption (particularly of fats and fat-soluble vitamins) from the digestive tract. These patients require pancreatic enzyme supplementation. Most patients also complain of severe and persistent *chronic pain*.

Acute Pancreatitis After a Vascular Procedure

Although rare, patients who undergo an endovascular procedure are at risk of atheroemboli (cholesterol embolism) dislodged by wires or stents. Cholesterol atheroemboli can lead to skin changes (e.g., blue toe, livedo reticularis) and/or gastrointestinal complications (e.g., acute pancreatitis, mesenteric ischemia). Pancreatitis can also result from ischemia (such as after being on heart bypass). Acute pancreatitis that results from uncorrectable causes such as atheroembolism and ischemia should be managed with supportive treatment (e.g., IV fluids, analgesia).

What Is the Most Common Indication for Surgical Management in Chronic Pancreatitis?

The most common indication for surgical intervention is *persistent and severe pain*. The reason why chronic inflammation leads to constant pain is not fully understood, but the mechanism proposed includes nerve injury in the pancreatic head. Nonoperative management, providing temporary pain relief, includes placement of a stent in the pancreatic duct, allowing for improved anterograde flow of pancreatic juices. For definitive treatment, the Puestow procedure (lateral pancreaticojejunostomy) is performed, in which the pancreatic duct is opened all the way from the head to the tail and sutured into the jejunum, allowing the free flow of pancreatic juices into the small intestine.

Areas of Controversy

Is Urgent ERCP Beneficial for Severe Pancreatitis?

Only if there is suspicion of concomitant cholangitis. In the absence of cholangitis, the theoretical benefit of urgent ERCP is to remove a gallstone impacted in the distal common duct that might cause ongoing pancreatic inflammation. However, studies have failed to consistently show benefit in

using urgent ERCP in the absence of cholangitis. This may be a result of ERCP having a 5% risk of causing pancreatitis, related to over-injection of contrast medium into pancreatic ducts, and due to the fact that the majority of gallstones pass into the duodenum spontaneously. There is evidence to support endoscopic removal of common bile duct stones with ERCP and papillotomy if cholangitis is also present. Some clinicians also choose to use ERCP in the setting of obstructive jaundice as suggested by persistent and marked bilirubin elevation.

Should Prophylactic Antibiotics Be Administered for Severe Acute Pancreatitis?

There is no role for antibiotics for mild pancreatitis, as the disease is due to inflammation, not infection. Patients with severe pancreatitis have increased mortality as a result of subsequent infections, justifying a possible role for prophylactic antibiotics, anecdotally supported by its use in clinical practice over the past several decades. However, its role has been scrutinized by multiple studies in recent years, with most concluding that there is no decrease in mortality with prophylactic antibiotics.

Areas Where You Can Get in Trouble

Missing Hypercalcemia as the Cause of Pancreatitis

In the absence of gallstones and alcohol abuse, the etiology of acute pancreatitis may be elusive. In a patient with hyperparathyroidism or hypertension controlled with hydrochlorothiazide, consider hypercalcemia as the etiology. Hydrochlorothiazide increases calcium reabsorption in the distal convoluted tubule. Hypercalcemia leads to a secretory block in the pancreatic duct. While *hypercalcemia* can cause pancreatitis, pancreatitis can cause *hypocalcemia*. Inflammation generates free fatty acids that avidly chelate insoluble calcium salts in the pancreatic bed, resulting in hypocalcemia. Thus, the predisposing hypercalcemia may be missed.

Pseudohyponatremia in Pancreatitis

Be aware of pseudohyponatremia in patients with hyperlipidemic pancreatitis. This is due to lipids displacing water, creating a measuring error. True sodium levels are normal.

Nutritional Support

If patients require being NPO greater than 7 days, nutritional support is needed. *Enteral nutrition* (not parenteral) is

preferred, with the feeding tube placed past the ligament of Treitz to avoid activation of the pancreas.

Summary of Essentials

History and Physical

- Nonsurgical conditions that mimic an acute abdomen: gastroenteritis, acute adrenal insufficiency, sickle cell crisis, diabetic ketoacidosis, acute porphyria, pelvic inflammatory disease, kidney stones, and pyelonephritis.
- Patients with pancreatitis typically present with epigastric pain radiating to the back, nausea, vomiting, anorexia, fever, and tachycardia.

Pathophysiology

- The initial event in pancreatitis is the inappropriate activation of pancreatic enzymes.
- Gallstones and alcohol are the most common causes of acute pancreatitis.

Diagnosis

- Most cases can be diagnosed with just a history, physical, and abnormal amylase/lipase.
- Ranson criteria are used to predict severity based on parameters during initial admission and at 48 hours after.

Workup

- Amylase/lipase levels do not correlate with severity of pancreatitis.
- In the absence of a history of alcohol abuse, start with a RUQ ultrasound to look for gallstones.

Management

- Patients should initially be managed conservatively with IV fluids, NPO, and narcotic analgesia.
- Gallstones.
 - Urgent ERCP rarely needed;
 - Early cholecystectomy if mild pancreatitis.
 - Late cholecystectomy if moderately severe or severe pancreatitis.
- If patients do not clinically improve after 3 days of conservative management, get a CT scan with contrast to look for any underlying complications (i.e., necrosis).
- Begin *enteral* nutrition in patients with prolonged NPO status or in severe acute pancreatitis.
- Refractory persistent abdominal pain is the main indication for surgery in chronic pancreatitis.

Complications

- Systemic
 - Early (first week)
 - Multi-organ failure
- Local
 - Late (3 weeks)
 - Pancreatic abscess
 - Pancreatic pseudocyst
 - Pancreatic necrosis

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Suggested Reading

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New Onset of Painless Jaundice

James X. Wu, Christian de Virgilio, Matthew Y. C. Lin, and Danielle M. Hari

Case Study

A 68-year-old man presents to the emergency department complaining of fatigue and intermittent vague abdominal pain. He denies nausea or vomiting, but “does not have much of an appetite these days.” He reports having lost almost 20 lbs in the past 2 months. He was recently diagnosed with type 2 diabetes, but he has no other medical problems and no previous surgery.

His stools have become lighter in color and his urine is much darker than before. His social history is negative for alcohol use, but he has a 50+ pack-year smoking history before quitting last year. He has no significant family history. On exam, he has a yellow hue to his eyes and tongue, along with scratch marks on his skin. A non-tender mass is palpated in the right upper

quadrant (RUQ) of the abdomen. Laboratory testing reveals total and direct bilirubin of 18 mg/dl (normal 0.2–1.3 mg/dl) and 9.2 mg/dl (<0.3 mg/dl), respectively, and alkaline phosphatase elevated at 215 μ /L (33–131 μ /L). Aspartate aminotransferase (AST) and alanine aminotransferase (ALT) are mildly elevated. CA 19-9 and CEA levels are normal.

Diagnosis

What Is the Differential Diagnosis of Jaundice?

What Is the Most Likely Diagnosis?

In a former smoker presenting with a new onset of painless jaundice accompanied by the constitutional symptoms of malignancy (e.g., weight loss), pancreatic cancer is the most likely

Table 21.1

Condition		Comments
<i>Prehepatic (hemolytic)</i>	Hemolytic anemia	Pallor, fatigue, shortness of breath
	Gilbert's syndrome	Benign condition triggered by overexertion, dehydration, menstruation, concurrent illness, surgery; decreased activity of the enzyme UDP-glucuronyl transferase
<i>Hepatic (hepatocellular)</i>	Ischemic liver injury	May result from transient hypotension and hypoxia or trauma or in transplanted donor liver; marked rise in ALT and AST
	Viral	Viral infection of hepatocytes; anorexia, nausea, vomiting; aminotransferases >25 \times upper limit of normal; may progress to acute liver failure, become a chronic infection, or completely resolve
	Toxic ingestion	Acetaminophen, alcohol (AST:ALT ratio > 2), iron overload; can cause acute liver failure
	Nonalcoholic fatty liver disease	Often asymptomatic; hepatic steatosis, metabolic syndrome, AST:ALT ratio < 1
	Primary biliary cirrhosis	Autoimmune process, skin xanthomas, associated with rheumatoid arthritis or Sjogren's syndrome; antimitochondrial antibody
	Primary sclerosing cholangitis	Associated with ulcerative colitis, fatigue, pruritus, p-ANCA
	Hepatolenticular degeneration (Wilson's disease)	Autosomal recessive, retention of copper, Kayser-Fleischer ring (brown ring on the edge of the iris), cirrhosis, and neurologic manifestations including parkinsonism
	Cirrhosis	Hyperestrinism (gynecomastia, testicular atrophy, decreased body hair, spider angiomas, palmar erythema), portal hypertension (esophageal varices, splenomegaly, ascites, caput medusae, anorectal varices), hepatic synthetic dysfunction (ecchymoses, edema, hydrothorax)
<i>Posthepatic</i>	Choledocholithiasis	Gallstone (from the gallbladder) enters the common bile duct (CBD) causing obstruction, RUQ pain, nausea
	Acute cholangitis	Ascending infection of the CBD often caused by gallstone obstruction; fever, jaundice, RUQ pain, \pm hypotension, \pm altered mental status
	Chronic pancreatitis	May cause biliary stricture, recurrent epigastric pain, malabsorption
	Mirizzi syndrome	RUQ pain due to external compression of the common hepatic duct by large gallstone in gallbladder or cystic duct
	Pancreatic carcinoma	Painless jaundice is more common in carcinomas arising from the head of the pancreas; new-onset diabetes may precede diagnosis of cancer; poor prognosis
	Ampullary carcinoma	Malignancy arising from the ampulla of Vater; most common presentation is painless obstructive jaundice
	Cholangiocarcinoma	Associated with sclerosing cholangitis, chronic parasitic infections, malignancy of the bile ducts usually present at advanced stage, highly lethal

diagnosis (more common than ampullary or cholangiocarcinoma). This is further supported by a Courvoisier's sign. New onset of type 2 diabetes in an older patient is associated with pancreatic cancer. Additionally, elevated levels of direct bilirubin and alkaline phosphatase further support the diagnosis.

History and Physical

What Is Courvoisier's Sign?

It is the presence of a palpable RUQ mass, which represents a non-tender, chronically enlarged gallbladder. It signifies obstruction, most often of the distal common bile duct, causing the biliary tree and the gallbladder to markedly distend, and is most commonly seen with malignancy (pancreatic, ampullary, or bile duct).

What Is the Implication of Painful Versus Painless Jaundice?

Painful jaundice implies an acute biliary obstruction, usually due to a gallstone, and is usually associated with inflammation/infection, such as acute cholangitis. Painless jaundice suggests a more insidious obstruction as seen with malignancy or autoimmune diseases of the biliary system. The absence of pain also suggests an absence of infection. However, pancreatic cancers can also be accompanied by mild, vague RUQ, epigastric, and back pain.

What Is Migratory Thrombophlebitis?

Also called Trousseau's sign, it is the development of superficial vein thrombosis in multiple extremities. It is a hypercoagulability associated with malignancy, most often pancreatic adenocarcinoma (as well as lung cancer). It involves localized tenderness and subsequent erythema along superficial veins of the trunk and extremities. This should not be confused with *necrolytic migratory erythema* which is a rash on the lower abdomen or perineum and is associated with glucagonomas.

Watch Out

Trousseau's sign is also a term used to describe an exam finding for hypocalcemia (tetany in the hand with inflation of a blood pressure cuff above systolic pressure for 3 minutes).

What Are the Risk Factors for Pancreatic Cancer? Cholangiocarcinoma? Gallbladder Carcinoma?

Risk factors for pancreatic cancer include chronic pancreatitis (strongest risk factor), smoking, tobacco, high-fat diet, obesity, male gender, and family history. While recent onset

of type 2 diabetes is also associated with pancreatic cancer, it is difficult to discern whether it is a risk factor or early symptom of disease. Patients with ulcerative colitis, especially with primary sclerosing cholangitis, are at increased risk for developing bile duct malignancy. Choledocholithiasis, particularly when associated with parasites, is considered a risk factor for bile duct cancer. Long-standing gallstone disease is associated with carcinoma of the gallbladder.

Where Is Jaundice Best Detected?

Examination of the skin should include the mucous membranes of the mouth (under the tongue), palms, soles, and sclerae. Areas that are not exposed to sunlight have more bilirubin due to lack of photodegradation. Rarely, excess consumption of carrots and other carotenoid-containing vegetables can cause yellowing of skin pigment, mimicking jaundice, without a change in the sclera or other mucous membranes.

What Is a Sister Mary Joseph Nodule? And What Is the Implication?

This is an umbilical nodule suggestive of carcinomatosis and is most commonly associated with gastric cancer but may represent any metastatic lesion from an intra-abdominal cancer. It was named after Dr. William Mayo's surgical assistant, who noted the nodes when prepping the abdomen of patients with gastric cancer who were found to have wide metastasis once the abdomen was explored.

What Is Blumer's Shelf?

A step-off felt during rectal exam suggesting metastatic disease to the pouch of Douglas. It is usually a site of metastasis of cancers of the lung, pancreas, and stomach.

Pathophysiology

What Causes Jaundice?

Jaundice can be caused by excess serum bilirubin due to hemolysis or impaired metabolism/excretion from the liver into the intestines. Jaundice becomes apparent at approximately bilirubin >2.5 mg/dl.

What Is the Metabolism of Bilirubin?

Bilirubin is the product of heme degradation. Breakdown of red blood cells occurs in the spleen, liver, and intravascular space. Initially, bilirubin is unconjugated (hydrophobic) and bound to albumin. Bilirubin is conjugated in the liver,

becoming water-soluble, and excreted into the duodenum. Intestinal bacteria convert conjugated bilirubin into urobilinogen, which can be reabsorbed into the systemic circulation, converted to urobilin, and excreted in the urine. Urobilin gives urine its yellow color. The remaining intestinal urobilinogen is converted to stercobilin and excreted in the stool. In direct hyperbilirubinemia, the bilirubin is excreted in the urine making it appear much darker or “Coca-Cola colored.”

What Is the Mechanism Behind “Clay-Colored” Stools?

Stool derives its brown color from stercobilin, a final product of bilirubin metabolism in the intestine. Biliary obstruction decreases bilirubin in the intestines, decreasing stercobilin and resulting in the “clay-colored” stool.

Workup

In a Patient with Obstructive Jaundice, What Would the Typical Laboratory Findings Be?

Conjugated/direct bilirubin, and consequently total bilirubin, will be increased in obstructive jaundice. Urine urobilinogen is decreased. Alkaline phosphatase (AP) level will also be elevated indicating bile duct obstruction.

How Do You Distinguish Between Jaundice from Biliary Obstruction (Posthepatic) and Hepatocellular Damage?

Hepatic causes of jaundice (such as hepatocellular injury from hepatitis) are usually nonsurgical problems, whereas posthepatic causes (such as biliary obstruction from acute cholangitis) are typically surgical. Distinguishing between the two is not always straightforward. Both will have some degree of elevation in total bilirubin, AST, ALT, gamma-glutamyl transpeptidase (GGT), and AP. AST and ALT are enzymes within the liver cells (though AST is also found in muscle and other cells). With hepatocellular injury, these enzymes are released. As such with hepatic causes, the AST and ALT (transaminases) can sometimes reach into the thousands and rise out of proportion to the AP. Such a disproportionate rise in the transaminases is indicative of hepatocellular damage, as seen in acute viral hepatitis, ischemic liver injury, or toxic insult. AP is present in the cells that line the bile ducts. A marked rise in ALP, out of proportion to the AST and ALT, is therefore indicative of posthepatic (biliary obstruction) pathology such as tumors or choledocholithiasis. Since ALP levels increase with many other diseases (such as bone pathology), a concomitant and proportionate rise in GGT is helpful, as it is more specific to liver disease.

What Initial Imaging Is Recommended for Painful Jaundice?

The initial test (■ Fig. 21.1) should be a RUQ ultrasound. Ultrasound is useful to detect gallstones and dilation of the biliary tree consistent with obstruction. Ultrasound is more likely to be the definitive study when the presentation is painful jaundice since gallstones are usually the cause.

What Is the Recommended Imaging Choice for Painless Jaundice?

For painless jaundice, since the suspicion for malignancy is high, the next study of choice is a “triple-phase” abdominal CT scan as ultrasound cannot rule out pancreatic lesions. Triple-phase CT captures images during three phases of contrast: (1) arterial phase, (2) early venous phase, and (3) late venous phase. A classic imaging finding is the “double duct sign,” which refers to the simultaneous dilatation of both the pancreatic duct and the common bile duct. Triple-phase CT can detect pancreatic and periaampullary masses and provide vital information regarding the resectability of the mass. Endoscopic ultrasound (EUS) is a useful adjunct that is utilized in some centers. EUS helps to better delineate the mass, detect smaller masses, detect vascular invasion, and identify enlarged lymph nodes. It can also identify other causes of biliary obstruction, such as a biliary stricture. In this latter case, brush cytology (of the bile duct) is useful to help determine if a stricture is benign or malignant. If CT/EUS does show a pancreatic mass suspicious for malignancy, FNA/biopsy is *not* necessary if patient is a surgical candidate.

What Is the Role of Magnetic Resonance Cholangiopancreatography (MRCP) and/or Endoscopic Retrograde Cholangiopancreatography (ERCP)?

MRCP and ERCP are not routinely needed. They are used to further delineate the biliary tree especially if no mass is seen, and as such, the cause of biliary obstruction is unclear. ERCP also permits stent placement or decompression if indicated. In cases where the history, exam, and imaging are suggestive of resectable pancreatic cancer, no further diagnostic workup is required.

What Is the Role of Tumor Markers CA 19-9 and Carcinoembryonic Antigen (CEA)?

There are insufficient data to use CA 19-9 or CEA as screening tools for early detection of pancreatic cancer. However, both CA 19-9 (in about 75%) and CEA levels (in about 45%) can be elevated in pancreatic cancer, as such these markers are sent in the presence of a pancreatic mass. CEA is also elevated in colorectal, breast, lung, ovarian, and prostate cancer (as well as in some benign conditions such as smoking and IBD).

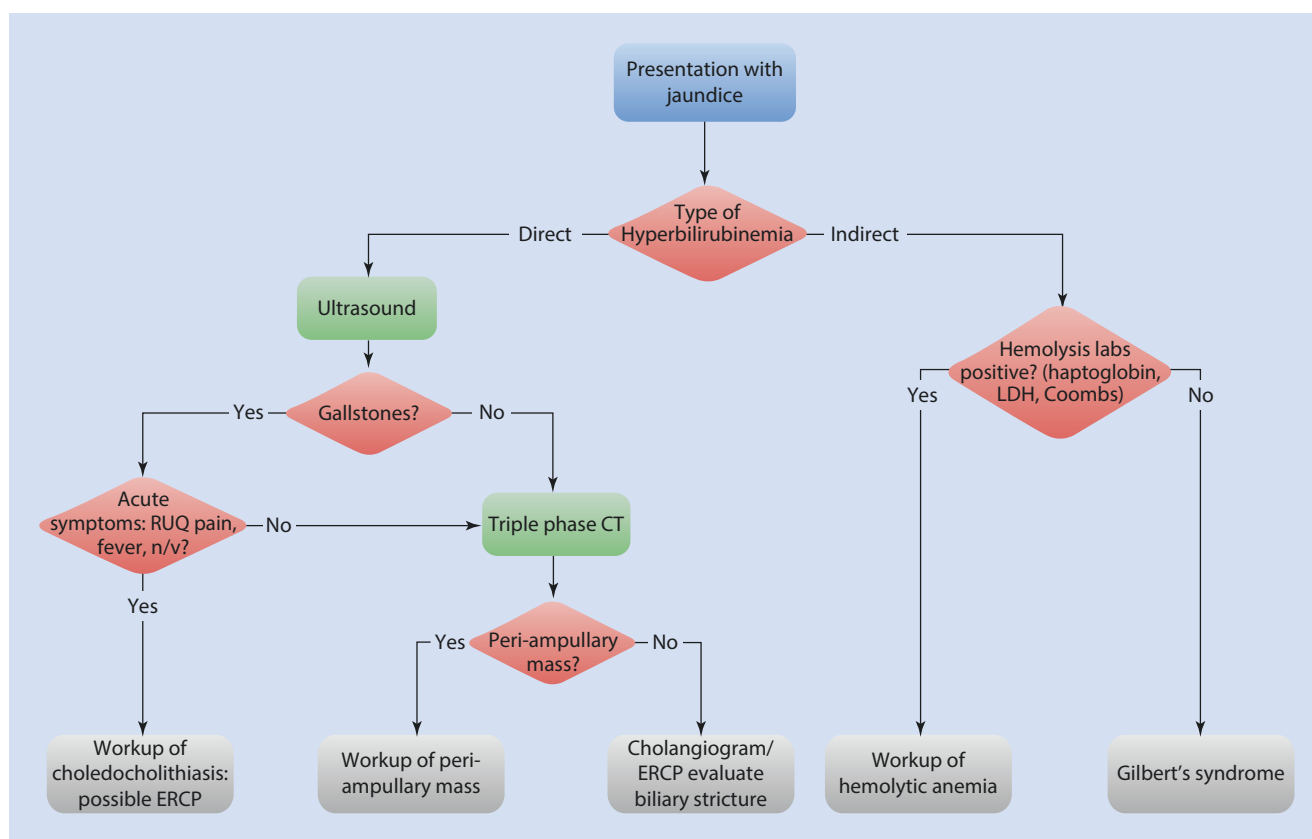


Fig. 21.1 Algorithm for presentation of jaundice

Management

What Criteria Make a Pancreatic Cancer Unresectable (Not a Surgical Candidate)?

Only about 15–20% of patients present with surgically resectable disease. It is considered unresectable if there is distant metastasis or it is locally invading or encasing local arteries (superior mesenteric artery, hepatic artery, or celiac trunk). Partial invasion of the veins (portal or superior mesenteric vein) is still potentially resectable (with partial vein excision and vein grafting).

Should Patients Who Present with Obstructive Jaundice and a Resectable Pancreatic Mass Undergo Biopsy Confirmation?

No. For patients with a resectable mass and no signs of metastatic disease, a biopsy is unnecessary. Given that the patient presents with obstructive jaundice, the mass needs to be resected regardless, and attempts at biopsy can create problems with sampling error and false negatives.

What Is the Role of Preoperative Stenting in the Presence of a Pancreatic Mass with Obstructive Jaundice?

There is no benefit to prophylactically decompressing (via ERCP and stenting) an obstructed biliary tree in the presence of pancreatic and periampullary cancers. In fact, decompression prior to pancreatic resection is associated with a higher postoperative infectious complication rate. Decompression should be reserved to relieve severe symptoms of obstructive jaundice (such as severe pruritus) or if there is evidence of sepsis from cholangitis.

What Is the Role of Neoadjuvant Therapy for Pancreatic Adenocarcinoma?

Neoadjuvant chemoradiation can make as many as one third of initially “borderline resectable” pancreatic cancers resectable, with the same expected survival as patients with initially resectable disease. There is a paucity of data regarding neoadjuvant therapy for nonpancreatic, periampullary cancers.

What Is the Surgical Management of Pancreatic Head (or Periampullary) Cancer?

The traditional surgical intervention for pancreatic head cancer has been a pancreaticoduodenectomy, also known as the Whipple procedure. This is best thought of in two stages: resection and re-anastomosis. The first stage involves resection of the head of the pancreas (pancreatectomy), duodenum (duodenectomy), proximal jejunum (jejunectomy), distal stomach (partial gastrectomy), gallbladder (cholecystectomy), and common bile duct. The second stage involved three anastomoses to the jejunum: pancreas to jejunum (pancreaticojejunostomy), common bile duct to jejunum (choledochojejunostomy), and proximal stomach to jejunum (gastrojejunostomy).

Why Must the Duodenum Be Removed When Surgically Resecting a Pancreatic Head Tumor?

The pancreas and the duodenum share the same blood supply (the pancreaticoduodenal arteries). Failure to remove the duodenum would lead to ischemic necrosis of that portion of the intestinal tract.

In Addition to Pancreatic Cancer, for What Other Conditions Is a Whipple Performed?

Cancer of the duodenum, cholangiocarcinoma, and ampullary carcinoma.

What Are the Options for Palliation in Patients Who Are Not Candidates for Pancreatic Resection?

Table 21.2

Condition	Options
<i>Chronic abdominal pain</i>	Celiac axis block, palliative external beam radiation
<i>Gastric outlet obstruction</i>	Gastrojejunostomy (allows oral feeding), open gastrostomy tube placement, or percutaneous gastrostomy tube
<i>Symptomatic biliary obstruction</i>	ERCP with biliary stenting (preferable), percutaneous cholecystostomy (may not adequately drain biliary tree), or hepaticojejunostomy (most invasive)

What Is the Most Common Complication that Is Specific to a Whipple/Pancreatectomy? What Are Some Other Pancreas Surgery Specific Complications?

Up to 40% of patients suffer a complication after the Whipple procedure. The most common complication is a delayed gastric emptying (gastroparesis) and is best treated with metoclopramide. Other postoperative complications include pancreatic leak/fistula, biliary leak/fistula, hemorrhage, malabsorption (loss of pancreatic enzymes), weight loss, and marginal ulceration.

Is There a High Risk of Diabetes After a Whipple Procedure?

The risk of postoperative diabetes is related to preoperative glucose levels. If the patient does not have diabetes preoperatively and has normal glucose levels, the risk of postoperative diabetes is low, as only the pancreatic head is removed.

How Do You Suspect/Diagnose a Postoperative Pancreatic or Biliary Leak?

Patients that undergo resection of the pancreatic head commonly have postoperative drains left in place. Normal drainage is serosanguinous or straw yellow-red in color. High hourly outputs of sanguineous drainage are concerning for hemorrhage. Green fluid suggests biliary leak. Milky gray-white fluid with a “sheen” on the bulb drain suggests pancreatic leak. To confirm the diagnosis of a pancreatic leak, drain fluid can be sent for fluid amylase, which should be significantly higher than serum levels.

Areas Where You Can Get in Trouble

Increased INR (PT) with Pancreatic Cancer

Bile is necessary for the absorption of vitamin K in the GI tract. Any disease process that leads to prolonged biliary obstruction (such as pancreatic cancer) will cause vitamin K deficiency and therefore a prolonged INR. This can be treated with parenteral vitamin K (if the patient is not actively bleeding) or fresh frozen plasma (if the patient is actively bleeding or needs immediate correction). Keep an eye out for fat-soluble vitamin (A, D, E, K) deficiencies in all patients with prolonged biliary disease.

Incidental Liver Findings on CT Scan

Hemangioma is the most common benign tumor of the liver and is often asymptomatic. Large (>10 cm) tumors can result in consumptive thrombocytopenia and high-output cardiac

failure, particularly in children. *Focal nodular hyperplasia* is found in the periphery of the liver, and the hallmark feature on CT imaging is a hypodense central stellate scar that enhances with contrast. It is often asymptomatic with no risk of rupture or subsequent malignancy. As such, resection is only indicated if a hemangioma or focal nodular hyperplasia is symptomatic (e.g., mass effect). *Hepatic adenomas* typically present in young women taking oral contraceptives. Due to a potential malignant transformation and risk up rupture, most clinicians recommend resection for all sized hepatic adenomas. Acute episodes of bleeding secondary to a ruptured hepatic adenoma should be managed with angioembolization.

Area of Controversy

Role of Adjuvant/Neoadjuvant Therapy in Pancreatic or Periapillary Cancer

The benefit of adjuvant (after surgery) therapy is currently under debate. Recent studies indicated that a combination of gemcitabine and capecitabine prolongs survival as compared to surgery alone. Others have shown benefit from 5-FU +/- radiation and gemcitabine. Earlier studies found that adjuvant 5-FU chemoradiation does not have a significant survival benefit, but 5-FU alone added 5 months of median survival compared to observation. Gemcitabine increased the disease-free survival by approximately 6 months without an improvement in median survival and has better outcomes than 5-FU but cannot be given with radiation due to toxicity. Recent studies have shown that neoadjuvant (before surgery) chemotherapy for locally advanced (nonresectable) pancreatic cancer has permitted downstaging, and successful subsequent surgery shows no benefit.

Summary of Essentials

History and Physical

- Malignant biliary obstruction suggested by:
 - Insidious onset of jaundice
 - Painless jaundice
 - Tea-colored urine
 - Clay-colored stool

Etiology/Pathophysiology

- Three categories of jaundice:
 - Prehepatic
 - Hemolytic anemia
 - Gilbert's syndrome
 - Hepatic
 - Ischemic liver injury

- Hepatic viral infection
- Toxic ingestion
- Nonalcoholic fatty liver disease
- Primary biliary cirrhosis
- Primary sclerosing cholangitis (mixed hepatic and posthepatic)
- Hepatolenticular degeneration (Wilson's disease)
- Cirrhosis
- Posthepatic
 - Choledocholithiasis
 - Acute cholangitis
 - Chronic pancreatitis
 - Mirizzi syndrome
 - Malignant biliary obstruction
- Most common causes of malignant biliary obstruction:
 - Pancreatic cancer
 - Cholangiocarcinoma
 - Ampullary carcinoma

Diagnosis

- LFTs (total bilirubin [direct/indirect], AST, ALT, ALP)
 - Amylase/lipase to rule out pancreatitis
- Imaging to evaluate for mass/stricture:
 - RUQ ultrasound
 - Triple-phase abdominal CT
 - EUS
- Routine stenting not recommended for malignancy prior to resection
- Biopsy not needed in the presence of mass causing obstructive jaundice
- +/- FNA, biopsy, brushings if stricture is seen and no mass.
- CEA/CA 19-9 if malignancy is suspected; role is controversial for periampullary and biliary malignancies

Management

- Periapillary masses:
 - Resectable: pancreaticoduodenectomy (pylorus sparing versus traditional)
 - Borderline resectable: consider neoadjuvant chemotherapy and repeat imaging to assess for surgical intervention
 - Unresectable:
 - Biliary stent and palliative chemotherapy
 - Surgical bypass (biliary and intestinal)

Watch Out

- Biliary obstruction associated with fever and pain may require urgent/emergent biliary decompression due to concern for cholangitis

Suggested Reading

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Question Set: Hepato-pancreaticobiliary

Questions

1. A 56-year-old male undergoes a Whipple procedure for pancreatic adenocarcinoma. Two days later, there is about 30 ml of white opaque drainage emanating from the patient's abdominal drain. What is the most appropriate next step?
- (A) Obtain abdominal CT scan
 - (B) Obtain abdominal ultrasound
 - (C) Send fluid for amylase level
 - (D) Start octreotide
 - (E) Initiate total parenteral nutrition (TPN)
2. Which of the following is an appropriate use of CA 19-9?
- (A) Screening normal, healthy patients for pancreatic cancer
 - (B) Screening at-risk patients for pancreatic cancer
 - (C) Confirming diagnosis of pancreatic cancer in patients with periampullary mass on CT
 - (D) Monitor for progression of disease following resection and/or adjuvant therapy
 - (E) None of the above
3. A 45-year-old female presents with a 1-day history of right upper quadrant (RUQ) pain and tenderness, nausea, and vomiting. Physical examination is significant for marked RUQ tenderness and guarding. Laboratory values are significant for a white blood cell (WBC) count of $12 \times 10^3/\mu\text{L}$ (normal $4.1\text{--}10.9 \times 10^3/\mu\text{L}$) with 10% bands, total bilirubin of 1.2 mg/dL (0.1–1.2 mg/dL), AST of 110 μL (normal 5–35 μL), ALT of 120 μL (7–56 μL), and alkaline phosphatase of 90 μL (33–131 μL). RUQ ultrasound reveals several gallstones, a thickened gallbladder wall, and a normal common bile duct. Optimal management consists of:
- (A) Schedule for elective outpatient laparoscopic cholecystectomy
 - (B) Admit, IV antibiotics, laparoscopic cholecystectomy within 48 hours of admission
 - (C) Admit, IV antibiotics for 4–5 days followed by laparoscopic cholecystectomy
 - (D) Admit, IV antibiotics until WBC normalizes, followed by outpatient laparoscopic cholecystectomy
 - (E) Admit, IV antibiotics, endoscopic retrograde cholangiopancreatography (ERCP), followed by laparoscopic cholecystectomy
4. A 40-year-old female presents with moderate epigastric abdominal pain. She has a history of intermittent right upper quadrant (RUQ) pain after eating fatty foods. She is afebrile with a heart rate of 100/min and blood pressure of 110/70 mmHg. She has moderate epigastric tenderness to palpation. Laboratory values are significant for a WBC of $11 \times 10^3/\mu\text{L}$ (normal $4.1\text{--}10.9 \times 10^3/\mu\text{L}$) with 3% bands, total bilirubin of 1.2 mg/dL (0.1–1.2 mg/dL), AST of 250 μL (5–35 μL), ALT of 300 μL (7–56 μL), alkaline phosphatase of 150 μL (33–131 μL), amylase of 1300 μL (30–110 μL), and lipase of 1100 μL (7–60 μL). RUQ ultrasound shows numerous small gallstones, normal gallbladder wall, and a normal common bile duct diameter. On the second

abdomen is distended but soft, and there is still significant epigastric tenderness. CT scan is obtained and shows diffuse edema surrounding the pancreas with a pancreatic phlegmon, but no evidence of necrosis. What is the most appropriate approach to his nutritional management?

- (A) Continue NPO and intravenous normal saline
 - (B) Clear liquid diet
 - (C) Enteral nutrition via nasojejunal feeding tube placed past ligament of Treitz
 - (D) Parenteral nutrition via central line
 - (E) Parenteral nutrition via peripheral line
9. A 52-year-old insulin-dependent diabetic man is evaluated for vague epigastric pain, is diagnosed with GERD, and is treated with proton pump inhibitors with resolution of symptoms. In the course of the workup, however, an abdominal ultrasound was performed. No gallstones were seen, but an incidental single 12 mm polyp was found within the gallbladder. What is the next best step in management?
- (A) Laparoscopic cholecystectomy
 - (B) Open cholecystectomy
 - (C) Percutaneous gallbladder drainage
 - (D) Endoscopic ultrasound
 - (E) Repeat ultrasound in 6 months
10. A 41-year-old man with alcoholism is admitted to the ICU with a diagnosis of severe acute pancreatitis. He requires aggressive fluid resuscitation to maintain his blood pressure in the first 24 hours, but over the next 3 days, his blood pressure stabilizes. On the third day of admission, he develops tachypnea, tachycardia, and hypoxia with oxygen saturation to 89%. Central venous pressure (CVP) is 8 mmHg. The patient is placed on nasal cannula, but the oxygen saturation remains the same. His temperature is 37.6 °C, pulse is 104/min, and blood pressure is 129/73 mmHg. A chest x-ray is obtained and shows bilateral infiltrates. Labs are drawn and shown below. What is the most likely diagnosis?
- AST: 75 μ /L (normal 5–35 μ /L)
 ALT: 92 μ /L (7–56 μ /L)
 WBC: $11 \times 10^3/\mu$ L (normal $4.1\text{--}10.9 \times 10^3/\mu$ L)
 Arterial blood gas: pH 7.44, PaO₂ 66 mmHg, PaCO₂ 36 mmHg
- (A) Acute respiratory distress syndrome (ARDS)
 - (B) Pulmonary embolism
 - (C) Hospital-acquired pneumonia
 - (D) Fluid overload (pulmonary edema)
 - (E) Atelectasis
11. Which laboratory finding is consistent with obstructive jaundice?
- (A) Decreased urine urobilinogen
 - (B) Decreased urine conjugated bilirubin
 - (C) Increased stool stercobilin
 - (D) Indirect > direct hyperbilirubinemia
 - (E) Elevation of transaminases out of proportion to alkaline phosphatase
12. Which of the following is a risk factor for pancreatic cancer?
- (A) Alcohol
 - (B) Smoking
 - (C) Prostate cancer in the family
 - (D) Malabsorption
 - (E) Pancreatic enzyme supplementation
13. A 60-year-old woman arrives to the emergency department with bloody emesis. She has a past medical history significant for hypertension and an episode of severe pancreatitis due to alcohol abuse 1 year ago and has since developed chronic pancreatitis.

jaundiced and has scleral icterus. He has fullness, suggestive of a mass in his RUQ that is not tender to palpation. What is the best term to describe this constellation of findings?

- (A) Cullen's sign
- (B) Charcot's triad
- (C) Reynold's pentad
- (D) Courvoisier's sign
- (E) Murphy's sign

17. A 46-year-old man is admitted to the hospital for severe epigastric pain of 12-hour duration, nausea, two episodes of vomiting, and anorexia. His past medical history is significant for alcoholism and several admissions for alcohol withdrawal. On physical exam temperature is 37.8 °C, blood pressure is 137/84 mmHg, pulse is 99/min, and respirations are 16/min. There is moderate tenderness in the epigastrium to palpation, but the abdomen is soft, and no masses are felt. There is no scleral icterus and no jaundice of the skin. Laboratory examination is shown below. What is the next step in management?

AST: 123 μ /L (normal 5–35 μ /L)

ALT: 99 μ /L (7–56 μ /L)

TBilli: 0.7 mg/dL (0.1–1.2 mg/dL)

Lipase: 709 μ /L (7–60 μ /L)

Alkaline phosphatase: 709 μ /L (33–131 μ /L)

WBC: $11 \times 10^3/\mu$ L (normal $4.1\text{--}10.9 \times 10^3/\mu$ L)

Hemoglobin: 12.9 mg/dL (13.2–16.2 mg/dL)

- (A) Start intravenous antibiotics
 - (B) CT scan
 - (C) ERCP with sphincterotomy
 - (D) NPO, IV hydration, and analgesics
 - (E) Chlordiazepoxide (Librium) for alcohol withdrawal
18. A 45-year-old healthy woman arrives for follow-up after her primary care physician discovered gallstones incidentally while performing imaging studies for an unrelated event. She has no complaints and has a healthy diet but is worried about the stones. An abdominal ultrasound is repeated and demonstrates several stones in her gallbladder without any wall thickening. What is the recommended management for this patient?
- (A) Prophylactic cholecystectomy
 - (B) Ursodeoxycholic acid
 - (C) Endoscopic retrograde cholangiopancreatography (ERCP)
 - (D) Observation
 - (E) Extracorporeal shock wave lithotripsy
19. A 58-year-old female underwent a CT scan of her abdomen and pelvis following a motor vehicle accident 1 month ago. She has no intra-abdominal injuries and was discharged from the emergency department. However, her gallbladder was incidentally noted to have scattered calcification. She is otherwise in good health and denies any abdominal pain. Her past history is significant for mild hypertension. Which of the following is the best recommendation?
- (A) Reassure patient that no follow-up is needed
 - (B) Repeat CT scan in 1 year
 - (C) Laparoscopic cholecystectomy
 - (D) Check serum calcium and parathyroid hormone (PTH) levels
 - (E) Obtain endoscopic retrograde cholangiopancreatography (ERCP) with brushings

gas-forming organisms, such as *Clostridia* and *E. coli*. Compared to acute cholecystitis, emphysematous cholecystitis is associated with a much higher mortality due to severe sepsis as the gallbladder becomes gangrenous. Broad-spectrum IV antibiotics and fluid replacement are started immediately to stabilize the patient, but because of the risk of gangrene, these patients should undergo an immediate cholecystectomy (B). The diagnosis can be supported with CT scan of the abdomen which will also demonstrate gas within the gallbladder wall but is not needed in this patient with a classic history and ultrasound findings (D). ERCP is not needed to diagnose emphysematous cholecystitis (E). Percutaneous cholecystostomy tube would not be an appropriate intervention for emphysematous cholecystitis as the necrotizing tissue infection would not be removed (C).

✓ 6. Answer A

The patient is manifesting evidence of a systemic infection (tachycardia, fever, and leukocytosis), and the presentation is most concerning for a pancreatic abscess. In patients with sepsis, the first steps include fluid administration, blood cultures, and prompt institution of intravenous antibiotics (within 1 hour) preferably imipenem if a pancreatic source is suspected. This should be followed by a CT scan with contrast looking for necrotic tissue (non-enhancing areas) and a possible pancreatic abscess (B). In the past, such a finding on CT would warrant immediate exploration for pancreatic debridement (D). However, the current approach is termed a “step-up” approach, which consists of (1) percutaneous or endoscopic drainage, (2) VARD, and (3) open necrosectomy (E). These procedures are termed external drainage. ERCP would be indicated for suspected acute cholangitis, usually in association with gallstones (C).

✓ 7. Answer C

Persistent diffuse abdominal pain, fevers, and nausea beyond a few days following laparoscopic cholecystectomy should raise suspicion of a bile duct injury or a bile leak from the cystic duct stump (due to the surgical clip inadvertently coming off). Imaging by CT scan should be obtained to look for a fluid collection. Abdominal ultrasound is also an acceptable imaging modality, but CT would be preferred in a patient with diffuse abdominal pain, while ultrasound would be preferred in localized RUQ pain. Additionally, findings on CT will guide subsequent management. Endoscopic ultrasound is primarily used in the setting of pancreatic or bile duct cancer to help determine resectability and look for adjacent enlarged lymph nodes (A). If the patient has evidence of infection, and a large fluid collection is found, a percutaneous drain should be placed. Bilious output suggests that the bile has leaked (from the stump of the ligated cystic duct or from an injury to the common hepatic/bile duct). A HIDA scan should be obtained next (E). If the common bile duct or common hepatic duct was inadvertently transected, the HIDA will show extravasation of tracer in the RUQ without tracer filling the small bowel. Such a finding would mandate exploratory laparotomy, and a loop of small bowel would need to be anastomosed to the proximal bile duct (hepaticojejunostomy). If on the other hand, the HIDA scan shows extravasation of tracer in the RUQ but tracer is seen in the small bowel, this confirms that the integrity of the main bile ducts are maintained. The most common cause for this latter finding is a cystic duct stump leak (as in the present case). Management is to perform ERCP with stenting of the ampulla (D). This lowers the pressure in the biliary tree, creating a path of least resistance for the bile, thus permitting the cystic duct stump to seal.

✓ 8. Answer C

Patients with mild pancreatitis can often be managed being NPO along with intravenous hydration alone since recovery occurs rapidly, within 5–7 days, at which time oral intake can resume. However, patients with moderate-severe pancreatitis are unlikely to resume oral intake within 5–7 days, prompting the need for nutritional support (A). In moderate-severe pancreatitis, oral feeding is not tolerated due to pain, nausea, or vomiting related to inflammation and edema causing gastric outlet obstruction (B). The most appropriate management is enteral nutrition. Enteral nutrition is provided

Interestingly, a family history of prostate cancer does not increase the risk for pancreatic cancer (C). Although malabsorption and pancreatic enzyme supplementation are frequently associated with patients that have chronic pancreatitis, they are not themselves directly linked to an increased risk for pancreatic cancer (D–E).

✓ 13. Answer E

UGI bleeding from varices most often are the result of alcohol-related liver cirrhosis with subsequent portal hypertension. This leads primarily to esophageal varices and less commonly to concomitant gastric varices. Isolated gastric varices are uncommon but occur in cases of sinistral or left-sided hypertension. The most common cause of sinistral hypertension is splenic vein thrombosis (SVT), which forces all the venous drainage of the spleen to travel through the short gastric veins resulting in large gastric varices that are at risk for rupture and bleeding. The most common cause of SVT is pancreatitis (acute or chronic). Peripancreatic inflammation can lead to occlusion of the splenic vein, which is posterior to the pancreas. SVT does not lead to esophageal varices because the collaterals do not involve the esophageal vasculature. Diagnosis of SVT can be made by duplex ultrasound of the splenic vein. It can also be detected on a venous phase CT scan. Splenectomy effectively resolves the enlarged short gastric veins and thus cures the gastric varices. Gastric varices are particularly dangerous as they tend to cause massive bleeding. In addition, they do not respond well to standard treatment for esophageal varices such as banding or sclerotherapy (B–C). Both liver transplantation and TIPS would reduce portal hypertension and thus help remedy esophageal varices but would be ineffective for isolated gastric varices in the setting of SVT (A, D).

✓ 14. Answer B

Acalculous cholecystitis is a condition seen in patients that are critically ill such as those with multiorgan trauma, burns, or recent major surgery (it is technically a type of cholecystitis and may appear with this terminology on the surgical shelf exam). The exact mechanism is unclear, but it is thought to be secondary to a combination of biliary stasis (from being NPO) and gallbladder ischemia as a result of hypovolemic and/or septic shock. The diagnosis can be difficult for several reasons. Patients are critically ill so a history may be unobtainable and physical exam may be unreliable. The imaging test of choice is ultrasound (US). Findings suggestive of acalculous cholecystitis include gallbladder wall thickening and pericholecystic fluid; however, such findings are not consistent. If US is not definitive, HIDA scan is the next test and is considered positive if the gallbladder is not visualized. However, false positives are seen in patients who have been NPO for a prolonged period (which many of these critically ill patients have). Gallstones are not implicated in this condition and will not be seen on ultrasonography. Treatment of acalculous cholecystitis includes broad-spectrum antibiotics followed by urgent percutaneous cholecystostomy tube (if the patient is critically ill) or cholecystectomy (laparoscopic vs. open cholecystectomy) if the patient is stable enough to undergo general anesthesia. Acute pancreatitis is in the differential; however, the patient's lipase is normal, and the amylase is only mildly elevated (A). Mild hyperamylasemia can be seen with many intra-abdominal conditions including cholecystitis or bowel ischemia. Burn victims are at risk for stress-related mucosal damage (curling ulcer) secondary to an inability to maintain the integrity of the gastrointestinal mucosal barrier. This may subsequently lead to perforated viscus which will present with an acute abdomen and a plain film demonstrating free air under the diaphragm (D). Cholangiohepatitis is associated with biliary parasites such as *Clonorchis sinensis* and is characterized by brown pigment stones that result from biliary sludge and dead bacterial cell bodies (C). Acute cholangitis would present with evidence of cholestasis (jaundice and/or elevated liver enzymes) and biliary obstruction (dilated bile ducts on ultrasound) (E).

✓ 15. Answer B

The most likely diagnosis is acute pancreatitis secondary to gallstones. More than half of all cases of pancreatitis are associated with either gallstones or alcohol. Patients with gallstone pancreatitis have extremely high serum amylase (sometimes in the

may recur once the medication is stopped. ERCP is an invasive procedure utilized for choledocholithiasis and acute cholangitis (C). Extracorporeal shock wave lithotripsy is effective in breaking the stones into small particles but does not prevent stone recurrence (E). This is more useful in patients presenting with nephrolithiasis (kidney stones).

✓ 19. Answer C

A calcified gallbladder is termed *porcelain gallbladder* and is most commonly found incidentally on imaging for unrelated reasons. Patients are often asymptomatic. However, it is important to recognize that a porcelain gallbladder with heavily scattered calcifications may be associated with an increased risk of gallbladder adenocarcinoma. As such, the recommendation is that patients with gallbladder that appear to have scattered calcification should undergo surgical management with laparoscopic cholecystectomy. Reassurance or “watchful waiting” with annual CT scan is not appropriate, even for asymptomatic patients, because of the risk for malignancy (A–B). In recent years, the association of small amounts of calcifications on the gallbladder and risk for malignancy has been re-examined, and most clinicians now recommend observation for these patients. There is no reason to suspect hyperparathyroidism, and so a serum calcium and PTH level would not be appropriate (D). ERCP with brushings is useful for suspected bile duct cancer, but not for suspected gallbladder cancer (E).

Lower Gastrointestinal

Beverley A. Petrie

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Bright Red Blood per Rectum

Tracey D. Arnell and Beverley A. Petrie

Case Study

A 72-year-old female presents to the emergency department reporting an episode of a large volume of bright red blood per rectum 4 hours earlier. She states that the toilet was filled with blood. The patient reports that the bleed was painless and was not associated with a bowel movement, and she thinks it stopped about 2 hours ago. She has never had rectal bleeding before. She denies fevers and chills. A colonoscopy 2 years ago only

demonstrated a few diverticula but no polyps. She has not lost weight recently. Her past medical history is significant for hypertension and chronic constipation. She has had no prior surgery. On physical examination, her blood pressure is 135/88 mmHg, and heart rate is 80/min. She is afebrile and has a normal respiratory rate. She appears to be pale and anxious. Cardiac and lung exams are normal. Abdominal exam reveals no surgical

scars and no masses. Her abdomen is non-distended, has normal bowel sounds, and is nontender to palpation, without rebound tenderness or guarding. Digital rectal exam reveals gross blood in the rectal vault but no masses. Anorectal exam shows no enlarged hemorrhoids and no fissures. Laboratory values reveal hemoglobin of 8 g/dL (normal 12–15.2 g/dL), hematocrit of 24% (37–46%), and normal mean corpuscular volume (MCV).

Diagnosis

What Is the Differential Diagnosis of a Lower GI Bleed (LGIB)?

Table 22.1

Disease		Etiologies	Risk factors	Clinical presentation
Diverticulosis (30–50%)		Arterial bleed from vasa recta at base of diverticula 90% of diverticula in sigmoid colon but 60% of diverticular bleeds from right colon	Advanced age, lack of fiber, obesity	Painless bright red blood per rectum (hematochezia)
Neoplastic (10–20%)		Colorectal adenocarcinoma may erode or ulcerate	Age > 50, black race, IBD, family history, sedentary lifestyle, smoking, obesity, diabetes	Large LGIB rare Iron-deficiency anemia and/or change in bowel habits
Iatrogenic		Up to 2 weeks post-polypectomy or biopsy	History of recent colonoscopy	Variable amount of bleeding occurring either immediately or days to weeks after the procedure (likely due to sloughing off of eschar)
Colitis (10–20%)	Infectious	CMV, Kaposi's enteroinvasive organisms: <i>Salmonella</i> , <i>Campylobacter</i> , <i>Shigella</i> , <i>EHEC</i> , <i>E. histolytica</i>	History of eating undercooked or contaminated foods or drinks Immunosuppression Travel history	Bloating, crampy abdominal pain and tenderness, fever, chills, bloody diarrhea
	Ischemic	Nonocclusive mesenteric ischemia secondary to low-flow state	Hypoperfusion secondary to hypotension, pressors, extreme exercise	Acute abdominal pain and tenderness; bloody diarrhea; chronic ischemia can result in stricture formation
	Inflammatory	Ulcerative colitis or Crohn's	Family history of IBD	Bloody diarrhea and mucus in stool; abdominal pain and cramping; previous episodes
	Radiation	Direct mucosal damage from radiation exposure resulting in arteriolitis	History of pelvic radiation	Bloody diarrhea, tenesmus (feeling of incomplete defecation), mucus discharge
Angiodysplasia (5–10%)		Aberrant blood vessels in the GI tract; venous in origin; usually right sided (cecum or ascending colon)	Advanced age; associated with von Willebrand's disease, CKD, aortic stenosis	Painless, often present with iron-deficiency anemia
Anorectal (5–10%)		Hemorrhoids—bleeding from the hemorrhoidal venous plexus within the anus	Pregnancy, constipation, straining; 4.4% of US population	Painless bright red blood with straining at bowel movement
		Anal fissures	Constipation, trauma, IBD, malignancies	Minimal blood usually on toilet paper; tear most commonly posterior midline; severe, tearing pain with defecation
		Rectal varices—bleeding is more proximal (within the rectum)	Portal hypertension	Massive painless bright red blood per rectum
		Rectal ulcers	Advanced age, debilitation, constipation; history of Crohns	Anterior location; blood and mucus per rectum, sense of incomplete evacuation

LGIB lower GI bleed, IBD inflammatory bowel disease, CMV cytomegalovirus, CKD chronic kidney disease, EHEC enterohemorrhagic E.Coli

Watch Out

LGIB can be due to a large upper GI bleed (UGIB). Always place a nasogastric tube to aspirate for blood or coffee grounds and to confirm that bile is obtained so that you know you have assessed for duodenal bleeding.

Watch Out

Diverticulosis is the most common cause of LGIB.

What Is the Most Likely Diagnosis?

An elderly patient with a recent colonoscopy demonstrating diverticula who presents with a large amount of bright red blood per rectum most likely has a LGIB from colonic diverticulosis. The most likely causes of a LGIB can be remembered by H-DRAIN:

- Hemorrhoids
- Diverticular bleeds
- Radiation colitis
- Angiodysplasia
- Infectious/ischemic/IBD
- Neoplasms/polyps

History and Physical**Why Is Age an Important Factor in a Patient with a LGIB?**

Acute LGIB in patients over age 50 is more likely to be diverticulosis, angiodysplasia, or malignancy, whereas in younger patients, the most common causes are infectious, hemorrhoids, anal fissures, and IBD.

Why Are the Onset and Duration of Bleeding Important?

Diverticular bleeding is arterial and as a result tends to present acutely with relatively large amounts of blood. Angiodysplasia and cancer are more chronic and more likely to present with anemia or dark stools.

What Do the Color and Amount of Blood Tell Us About the Source of Bleeding?**Watch Out**

Right colonic diverticula are more likely to bleed, while left colonic diverticula are more likely to get infected.

Table 22.2

Color, amount of bleeding	Possible source(s)
<i>Dark maroon, mixed with stools</i>	Upper GI, small intestine, right colon
<i>Copious bright red blood (hematochezia)</i>	Right colon (e.g., diverticulum), rectum, anus, massive upper GI bleed with rapid transit
<i>Spots of blood on toilet paper, dripping after defecation</i>	Rectum, anus
<i>Scant, dark red blood</i>	Angiodysplasia
<i>Occult</i>	Polyp, colorectal cancer

What Is an Occult Bleed?

Occult bleeding means that the patient does not see any blood per rectum. The bleeding is only detected by fecal occult blood testing/fecal immunochemical testing or by finding iron-deficiency anemia. Occult bleeding (particularly in older patients) raises suspicion for malignancy (especially colorectal cancer), and in younger patients, it may be due to inflammatory bowel disease (IBD) or due to familial cancer syndromes (e.g., familial adenomatous polyposis, hereditary nonpolyposis colorectal cancer).

What Associated Symptoms Are Important to Look for, and How Do They Help in the Differential Diagnosis?

Systemic symptoms such as fever and bloody diarrhea may indicate an infectious or inflammatory cause. Recurrent symptoms in younger patients are suspicious for IBD. Weight loss should raise suspicion for malignancy, especially in older patients who have changes in bowel habits and/or iron-deficiency anemia. Bleeding that follows straining at stool suggests an anorectal cause. In this latter setting, painless bleeding suggests internal hemorrhoids; whereas anal pain is suggestive of anal fissures (bleeding with fissures is usually minimal). Tenesmus, a sense of incomplete evacuation of stool, is most often seen with ulcerative colitis and infectious etiologies. Bleeding from diverticulosis and angiodysplasia tends to be painless. Abdominal pain (especially in elderly patients) should raise suspicion for ischemic colitis (particularly in the setting of low-flow states).

Watch Out

Bloody diarrhea following recent travel to endemic areas raises suspicion for infectious causes. Patients with watery, progressing to bloody, diarrhea, and no fever should always be evaluated for *EHEC*.

Why Is a History of Pelvic Radiation or Prior Aortic Surgery Important?

Radiation can cause damage to the rectal mucosa, leading to radiation proctitis. There are two forms. *Acute radiation proctitis* occurs in days to weeks after pelvic radiation treatment and presents with rectal bleeding and pain secondary to ulceration and sloughing of the rectal mucosa. This is often a self-limiting condition and resolves with discontinuation of radiation therapy. *Chronic radiation proctitis* occurs years after radiation therapy, and unlike acute radiation proctitis, rectal bleeding is less common. Patients with chronic radiation proctitis may develop strictures, fistulas, and bowel obstruction. Acute radiation proctitis does not increase risk for the development of chronic radiation proctitis. Aortic surgery rarely results in erosion of the aortic graft into the duodenum, leading to an aortoduodenal fistula.

Why Should One Inquire About Alcohol History and Look for Stigmata of Liver Cirrhosis?

Liver disease can lead to coagulopathy and portal hypertension. Although portal hypertension most commonly causes esophageal varices and upper GI bleeding, varices can also form in the rectal veins of the lower GI tract due to their systemic and mesenteric connections.

What Medications Can Exacerbate GI Bleeding?

Anticoagulants such as warfarin, aspirin, clopidogrel, and NSAIDs can exacerbate GI bleeding.

What Is the Implication of Abdominal Tenderness on Physical Examination?

Abdominal tenderness is highly suggestive of colitis such as from IBD, ischemic colitis, or infectious diarrhea. Abdominal tenderness is unusual with bleeding from diverticulosis and angiodysplasia.

Can Upper and Lower GI Bleeds Be Distinguished Based on History and Physical Exam?

Sometimes. Vomiting of blood or coffee grounds, in conjunction with maroon or black stools, is indicative of an upper GI bleed. Bright red blood per rectum is usually a LGIB (the exception is the patient with massive upper GI bleed). Maroon stools, in the absence of vomiting, can be either an

upper or lower GI source. Anoscopy/proctoscopy should be part of the initial physical exam.

What Is the Significance of Finding Iron-Deficiency Anemia in Association with a LGIB?

Iron-deficiency anemia in a man or a postmenopausal woman should raise suspicion for malignancy (especially right-sided colorectal cancer, particularly if the patient has never had screening). Although colorectal cancer usually causes occult bleeding, it may manifest as a larger, acute bleed when the cancer causes erosion through or ulceration of the bowel wall.

How Does Ischemic Colitis Classically Present?

Ischemic colitis typically presents with left-sided abdominal pain and bloody diarrhea in elderly patients with low-flow states, such as those with severe volume depletion, heart failure, shock, and trauma.

What Are the Risk Factors for Diverticulosis?

Older individuals (60% of people over age 60 have diverticulosis) from Western countries or those who consume diets that are low in fiber, high in fat, and high in red meat are at risk. Obese individuals are also at increased risk. Inherited connective tissue disorders, such as Marfan's syndrome and Ehlers-Danlos syndrome, can also increase the likelihood of diverticulum formation.

Etiology/Pathophysiology

What Is a Diverticulum?

A diverticulum is defined as a saclike protrusion through the colonic wall. The presence of diverticula is known as diverticulosis or diverticular disease. As a diverticulum herniates, the vasa recta become draped over the dome of the diverticulum, at which point it is only separated from the lumen by mucosa. Chronic damage and stress on the luminal side of the vasa recta lead to weakness of the arterial walls, eventually resulting in rupture.

What Causes a Diverticulum?

High intraluminal pressure in the colon can cause the mucosa and submucosa to herniate through the muscular layer of the intestinal wall. Since not all layers are included, this is considered a false diverticulum.

What Is the Difference Between Diverticulum, Diverticulosis, and Diverticulitis?

Table 22.3

Name	Features
Diverticulum	Saclike protrusion through the colonic wall
Asymptomatic diverticulosis	No symptoms in a patient with diverticula
Symptomatic diverticulosis	Bleeding diverticula
Diverticulitis	Microperforation or macroperforation of inflamed diverticula

What Is the Most Common Site of Diverticula? Why?

Ninety percent of diverticula occur in the sigmoid colon. As stool moves distally through the colon, water is reabsorbed, and it becomes harder. The left colon must contract more to get the stool to pass. The combination of harder stool and thickened muscular wall causes increased pressure and makes diverticulum formation more likely. The muscular layers (taenia) splay out at the rectosigmoid junction covering all of the rectum which is why diverticula do not appear in the rectum.

How Common Is a Diverticular Bleed?

Although a diverticular bleed is the most common cause of an acute LGIB in patients over 50, it occurs in only a small percentage (3–5%) of patients with diverticulosis.

What Is the Natural History of a Diverticular Bleed?

Seventy percent stop bleeding spontaneously. Each episode of a diverticular bleed increases the risk of a future bleed.

Watch Out

Significant GI bleeding from a diverticulum is from diverticulosis. Diverticulitis is not usually associated with bleeding.

What Is Angiodysplasia? What Are the Risk Factors?

Angiodysplasia refers to focal submucosal areas of thin, weak, and dilated (ectatic) vessels in the GI tract, most commonly in the cecum and right colon in individuals over age 60. It is the most common vascular abnormality of the GI

tract. Incidence increases with age, likely due to degeneration of the vascular walls. Bleeding is typically small in quantity or occult, often resulting in iron-deficiency anemia and intermittently heme-positive stools but may present with larger bleeds. Unlike diverticular bleeds, which are arterial in origin, acute angiodysplasia bleeds generally produce less bleeding because their origin is venous. Angiodysplasia is associated with von Willebrand's disease, aortic stenosis, and chronic kidney disease.

What Causes Ischemic Colitis?

The pathophysiology is decreased blood flow to the colon, causing nonocclusive (meaning not due to arterial thrombosis or embolism) ischemic colitis. The mucosa is affected first, and depending on the severity of the ischemia, progression may occur through all layers of the colon. The most common areas to be affected are “watershed” areas which have relatively poor perfusion as they are in between two areas of the colonic blood supply. In most cases, the ischemia is not transmural, meaning it does not affect the entire bowel wall, and most patients will recover after correction of their “low-flow” state.

What Factors Can Precipitate Ischemic Colitis?

The factors that can precipitate ischemic colitis are volume depletion, heart failure, shock, cardiovascular surgery, hypercoagulable states, extreme exercise, hemodialysis, recent aortic surgery, and certain drugs (e.g., digitalis, vasopressors, cocaine).

What Are the Primary Watershed Areas of the GI tract?

The most commonly affected watershed area in low-flow states is *Griffith's point* located at the splenic flexure where collaterals are present between the superior mesenteric and inferior mesenteric arteries. *Sudeck's point* is located at the rectosigmoid junction where collaterals are present between the sigmoid and superior rectal artery.

Watch Out

The rectum has a dual blood supply, so rectal mucosal ischemia is very rare.

What Is the Natural History of Ischemic Colitis?

Most cases of ischemic colitis will resolve with supportive measures, while a minority of cases will require resection for transmural (i.e., full thickness of the colonic wall) infarction.

What Are the Differences Between Ischemic Colitis and Acute Mesenteric Ischemia?

Table 22.4

	Ischemic colitis	Acute mesenteric ischemia
<i>Patho-physiology</i>	Hypoperfusion due to low-flow state; ↓BP, ↓CO; due to volume depletion, heart failure, extreme exercise, vasoconstricting drugs or recent aortic surgery	Arterial embolus to SMA (usually from atrial fibrillation) or thrombosis (from underlying atherosclerosis in SMA)
<i>Natural history</i>	80% resolve spontaneously with supportive care (e.g., fluids, IV antibiotics, blood pressure management)	Usually leads to bowel necrosis requiring resection; high mortality
<i>Most commonly affected territories</i>	Segment of colon between arterial supplies, known as watershed areas	Small bowel (from ligament of Treitz) to mid-transverse colon
<i>Layers of bowel affected</i>	Usually mucosa only	Often transmural (i.e., all layers)
<i>Diagnosis</i>	Colonoscopy often shows mucosal changes	CT scan often shows small bowel wall thickening, occlusion of SMA, and gas in the intestinal wall (known as pneumatosis)

BP blood pressure, CO cardiac output, SMA superior mesenteric artery, IMA inferior mesenteric artery

Initial Management

What Are the Initial Steps in the Management of a LGIB?

The first step is to place two large-bore IVs and send laboratory tests including a type and cross, complete blood count, chemistry, and INR/PTT. If the patient demonstrates evidence of significant blood loss, resuscitation should be instituted with crystalloid (normal saline or lactated Ringer's) followed by packed red blood cells as needed. A microcytic anemia raises suspicion for an underlying iron-deficiency anemia due to occult blood loss from colorectal cancer but may also indicate a chronic bleed from angiodysplasia. Leukocytosis is often seen in infectious or inflammatory etiologies.

What Is the Next Step?

In an unstable patient with a large volume LGIB, an upper GI bleed source needs to be ruled out. This can be done most expe-

ditiously via upper endoscopy. Alternatively an NG tube can be placed. Up to 10% of cases of hematochezia are due to massive UGIBs. If the NG tube aspirate is positive for blood or coffee grounds (partially digested blood), then the patient has an UGIB, and an esophagogastroduodenoscopy (EGD) is indicated. If the NG aspirate returns with bile (confirming the tip of the tube is in the duodenum) but without blood, this rules out an UGIB. If the NG aspirate returns clear fluid (gastric juice) without blood, it rules out a bleed from the stomach, but does not rule out an UGIB from the duodenum. A criticism of the NG tube test is that it may have low sensitivity and a low negative likelihood ratios.

How Does the Hemodynamic Stability of the Patient Affect the Subsequent Management and Diagnostic Workup?

A hemodynamically unstable patient needs admission to the ICU for careful monitoring. In addition, further workup to find the source of bleed needs to be performed expeditiously. Most LGIB stop spontaneously. Thus, the need for urgent surgery as well as mortality is significantly less than for an UGIB.

What Is the First Diagnostic Test of Choice in an Unstable Patient? How Effective Is This Test in Visualizing the Source of LGIB in the Acute Setting?

Colonoscopy is the first test of choice. Ideally the patient should first undergo a rapid bowel prep to cleanse the bowel, in which case the colonoscopy is performed the subsequent day. However, if the patient is rapidly bleeding, colonoscopy is done urgently without the bowel prep. Sometimes, if the bleeding is brisk, the blood itself can act as a cathartic, allowing visualization. Often though, the colon is filled with blood and stool, so that colonoscopy may fail to adequately visualize the bleeding site. However, it can generally determine whether the bleed is coming from somewhere within the colon or from proximal to the ileocecal valve (small bowel). This determination has important diagnostic and therapeutic implications. Colonoscopy cannot visualize the small bowel.

What If This Diagnostic Test Is Not Able to Visualize the Bleeding? What Are the Two Options for Localizing the Source of Bleed? What Are the Advantages/Disadvantages of Each Modality?

If the patient is continuing to bleed, the next step is to perform either diagnostic arteriography or a tagged red blood cell scan (nuclear scintigraphy) using technetium-99 m. The decision to choose one over the other depends on the

suspected rate of bleeding and the availability of these modalities. The advantage of the arteriography is that the study can be both diagnostic and therapeutic (the area of bleeding can be embolized). However, arteriography is invasive, and bleeding must be brisk (about 0.5–1 ml/min) to see it. It is also not feasible to repeatedly perform arteriography if the patient stops bleeding and then rebleeds. Nuclear scanning detects bleeding at a much slower rate (only 0.1 ml/min), and since the radioactive agent remains labeled on the red blood cell for some time, repeat images can be obtained for up to 24 hours. Nuclear scanning does not permit therapy and is not able to pinpoint the exact vessel/location of the bleed but rather the general area.

What Is the Next Step If These Modalities Fail to Identify the Exact Source of Bleeding?

This depends on whether the bleeding has ceased and if the patient is stable or whether the bleeding is continuing and the patient is unstable. The next step also depends on whether the bleeding is thought to be coming from the colon or small bowel. If the bleeding has stopped and the source is thought to be the small bowel (i.e., blood was seen on colonoscopy above the ileocecal valve), then small bowel studies are performed. These include a Meckel's nuclear scan (to look for bleeding from a Meckel's diverticulum), capsule endoscopy (barium study of the small bowel), and enteroscopy (fiber-optic scope of the proximal small bowel). If the bleeding has stopped and the source is not clear or is thought to be somewhere in the colon, repeat colonoscopy, nuclear scan, and/or arteriography can be considered if and when the patient rebleeds. If the bleeding has not stopped and the patient is unstable, emergent *exploratory laparotomy* is recommended with total colectomy leaving the rectum, and end ileostomy, provided that the source of bleeding has been confirmed to be coming from somewhere (distal to the ileocecal valve and proximal to the rectum) either preoperatively or with intraoperative (on-table) endoscopy. This can be as confirmed by nuclear scan, arteriography, or colonoscopy (fresh blood in colon and no blood coming from above ileocecal valve).

What If Arteriography Localizes the Source of Bleeding But Is Unable to Stop the Bleeding with Embolization?

If bleeding is ongoing, surgery is recommended. Resection is determined by the localization (i.e., right colectomy for bleeding localized to the right colon).

Areas Where You Can Get In Trouble

Bleeding After Colonoscopic Biopsy or Polypectomy

Bleeding after a colonoscopic biopsy can occur even several weeks later. It is important to obtain this history. Initial treatment consists of endoscopic injection of vasoconstrictive agents (e.g., epinephrine), cauterization, or clipping.

Pneumoperitoneum After Colonoscopy

Pneumoperitoneum (free air under the diaphragm) almost always requires surgical intervention, as it implies bowel perforation. In the case of pneumoperitoneum after a colonoscopy, however, intervention is not always necessary. The insufflation and manipulation of the endoscope by the provider can result in microperforation of the colon leading to benign pneumoperitoneum. In a patient that is hemodynamically stable, afebrile, and with no abdominal pain or tenderness, pneumoperitoneum after colonoscopy can be conservatively managed with bowel rest, broad-spectrum antibiotics, and serial abdominal exams.

Summary of Essentials

History and Physical

- Color, quantity, and duration of bleeding are important.
- Ask about anticoagulants and antiplatelet agents.
- Right colon diverticulosis, most common cause of LGIB.
- Hematemesis/coffee ground emesis indicates UGIB.
- Digital rectal exam, anoscopy/proctoscopy.

Pathophysiology

- Diverticulosis
 - Increased intraluminal pressure (low-fiber diet)
 - Most common cause of LGIB
 - Right colon diverticula bleed (brisk and arterial)
 - Left colon diverticula get infected
- Angiodysplasia
 - Associated with aortic stenosis and kidney disease
 - Bleeding is slower (venous)
- Colon Cancer
 - Iron-deficiency anemia in males or postmenopausal females should raise suspicion for colon cancer (particularly right-sided cancers)
 - Massive LGIB rare

- Colitis
 - Inflammatory
 - Infectious
 - Ischemic

Management

- Fluid resuscitation, NG tube to rule out UGIB, if large bleed admit to ICU
- Diagnostic studies
 - Colonoscopy
 - Nuclear-tagged RBC scan
 - Arteriography
- Most cases of LGIB will stop spontaneously
- Indications for surgery
 - Hemodynamically unstable despite resuscitation
 - Massive bleeding > 6 units PRBC
 - Active bleeding with failure of embolization

Suggested Reading

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Right Lower Quadrant Abdominal Pain

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Case Study

A 25-year-old male presents to the emergency department with a 1-day history of periumbilical abdominal pain which has now shifted to the right lower quadrant. He describes the pain as constant and a 7/10. After the onset of pain, he subsequently developed nausea and has vomited twice. He has not eaten for 24 hours due to a lack

of appetite. Physical examination is significant for a temperature of 38 °C, absent bowel sounds, and marked tenderness to palpation at 1/3 the distance from the anterior superior iliac spine to the umbilicus. When palpating in the left lower quadrant (LLQ), he reports pain in the right lower quadrant (RLQ). Active flexion of his right

hip and internal rotation of the right leg reproduce the pain. His skin in the RLQ is hypersensitive to touch. There is no rebound tenderness. Laboratory values are significant for a white blood cell (WBC) count of $13.5 \times 10^3/\mu\text{L}$ (normal $4.1\text{--}10.9 \times 10^3/\mu\text{L}$), with 15% bands. The urinalysis demonstrates 1+ WBCs without bacteria.

Diagnosis

What Is the Differential Diagnosis for Acute Appendicitis in an Adult? How Can Other Diagnoses Be Confused with Appendicitis?

Table 23.1

Diagnosis	History and physical	Mimicking features
<i>Inflammatory bowel disease (IBD)</i>	Abdominal pain, severe cramps, weight loss, bloody diarrhea, anemia, enterocutaneous fistula/anal fissures (Crohn's), toxic megacolon (ulcerative colitis)	Crohn's can present with RLQ pain due to inflammation limited to the ileocecal region (known as regional enteritis)
<i>Pancreatitis</i>	Epigastric pain radiating to the back, nausea, vomiting, anorexia, fever, tachycardia, cholelithiasis, or alcohol abuse	Predominantly epigastric pain, with severe pancreatitis, ascites forms and may track down the right paracolic gutter (depressions found between the colon and abdominal wall) causing RLQ pain
<i>Cholecystitis</i>	Right upper quadrant (RUQ) pain radiating to back, nausea, vomiting, fever, Murphy's	Though pain is typically RUQ, a large inflamed gallbladder may cause RLQ pain
<i>Appendicitis</i>	Anorexia, vomiting, vague periumbilical pain shifting to localized RLQ pain (<i>McBurney's point</i>), Rovsing's, psoas, and obturator signs	–
<i>Gastroenteritis</i>	Nausea, vomiting, watery diarrhea (viral), bloody diarrhea (certain bacteria), myalgia, fever	May cause diffuse abdominal tenderness and marked leukocytosis
<i>Nephrolithiasis</i>	Colicky flank pain that may radiate to inner thigh or genitals, nausea, vomiting, dysuria, hematuria	Ureteral pain may refer to RLQ
<i>Perforated duodenal ulcer (Valentino's syndrome)</i>	Sudden onset of epigastric pain, rigid abdomen, history of dyspepsia, NSAID use, recurrent ulcers, <i>H. pylori</i> infection	Initial pain is epigastric, then diffuse, but duodenal perforation may seal, enteric contents may track down right paracolic gutter causing subsequent RLQ pain
<i>Pyelonephritis</i>	Costovertebral angle (CVA) tenderness, fever, pain on urination, vomiting	Renal and ureteral pain can refer to RLQ
<i>Sigmoid diverticulitis</i>	Pain in LLQ, fever, leukocytosis, nausea, diarrhea, constipation, common in elderly	A large, floppy, redundant sigmoid colon may lie in the RLQ
<i>Cecal diverticulitis</i>	Congenital solitary diverticulum	Identical to appendicitis
<i>Meckel's diverticulitis</i>	"Rule of 2's": males get complications 2x more commonly than females, occurs within 2 ft of the ileocecal valve, 2 types of tissue (pancreatic, gastric), found in 2% of the population, can present at 2 years of age (with <i>painless rectal bleeding</i>)	Identical to appendicitis, in an adult, a Meckel's diverticulum can become infected (<i>Meckel's diverticulitis</i>) and present with RLQ pain

What Other Conditions Should You Consider in the Differential Diagnosis for Acute Appendicitis in Women?

Table 23.2

Diagnosis	History and physical
<i>Pelvic inflammatory disease</i>	<i>Neisseria gonorrhoeae</i> or <i>Chlamydia</i> infection, purulent cervical discharge, cervical motion tenderness, adnexal tenderness, dysuria
<i>Ovarian torsion</i>	Acute onset of severe pelvic pain, adnexal mass, history of ovarian cysts
<i>Mittelschmerz</i>	Physiologic recurrent mid-cycle pain, mild and unilateral, duration ranges from few hours to few days, normal pelvic exam
<i>Ruptured ectopic</i>	Typically presents 6–8 weeks after last normal menstrual period, abdominal pain, amenorrhea, vaginal bleeding, breast tenderness, anemia (rarely hemorrhagic shock)

What Other Conditions Should You Consider in the Differential Diagnosis for Acute Appendicitis in a Child?

Table 23.3

Diagnosis	History and physical
<i>Mesenteric lymphadenitis</i>	Concomitant or recent upper respiratory infection; high fever; enlarged, inflamed, and tender lymph nodes in small bowel mesentery; generalized abdominal pain
<i>Yersinia enterocolitica (pseudoappendicitis)</i>	RLQ pain, fever, vomiting, bloody diarrhea, history of sick contacts (e.g., infected children at daycare)
<i>Gastroenteritis</i>	Nausea, vomiting, watery diarrhea (viral), bloody diarrhea (certain bacteria), myalgia, fever
<i>Intussusception</i>	Nausea, vomiting, crampy abdominal pain, “red currant jelly” stool, “sausage-shaped mass in abdomen (12-month-old infant)

What Is the Most Likely Diagnosis?

Given the history of initial periumbilical pain that is now localized to the RLQ and subsequently followed by nausea/emesis and leukocytosis with increased bands, the most likely diagnosis is acute appendicitis.

Watch Out

Don't forget to rule out an ectopic pregnancy with a beta-hCG pregnancy test for *all* women of childbearing age presenting with abdominal pain.

History and Physical

What Is Usually the First Symptom of Appendicitis and What Is the Classic Sequence of Symptoms?

In >95% of cases of acute appendicitis, anorexia is the first symptom. The classic sequence of symptoms is anorexia, vague periumbilical abdominal pain, nausea, vomiting, and then a shift to localized RLQ pain.

Watch Out

Nausea preceding abdominal pain is more consistent with gastroenteritis.

What Is the Significance of Absent Bowel Sounds?

Absent bowel sounds indicate a paralytic ileus which is seen in association with inflamed/infected bowel (such as acute appendicitis). It would be less likely found with gastroenteritis.

What Is a Hamburger Sign?

The majority of patients with acute appendicitis will have anorexia. If the patient is hungry, acute appendicitis is less likely. Inquire about the patient's favorite food (e.g., hamburger, pizza), and ask if the patient would like to eat it. Patients with true anorexia will decline their favorite food (positive hamburger sign). Children may not follow this sign.

What Are Rovsing's, Psoas, and Obturator Signs and McBurney's Point Tenderness?

Appendicitis creates an inflammatory response in the adjacent retroperitoneum and parietal peritoneum. These are signs (Table 23.4) of localized peritonitis in the RLQ due to inflammation. *Rovsing's sign* is right lower quadrant pain with palpation of the left lower quadrant. Compression in the LLQ stretches the abdominal wall triggering pain in the inflamed underlying RLQ parietal peritoneum. Appendicitis can also inflame the adjacent psoas or obturator muscles. *Psoas sign* is RLQ pain on passive extension of the right hip or active flexion of the right hip. *Obturator sign* is RLQ pain

Table 23.4 Signs of appendicitis

Sign	Description	Appendix location
<i>Rovsing's</i>	RLQ pain with palpation of LLQ	Normal (intraperitoneal)
<i>Psoas</i>	RLQ pain on passive extension of the right hip or active flexion of the right hip	Retrocecal
<i>Obturator</i>	RLQ pain on internal rotation of the hip, typical of a pelvic appendix	Pelvic
<i>McBurney's</i>	Tenderness to palpation at McBurney's point	Any



Fig. 23.1 McBurney's point. A. McBurney's point marked for mini incision. (B) Incision appearance on postoperative day 4. The procedure began by making a small incision, 1.5–1.8 cm in length, according to the thickness of abdominal wall, at McBurney's point. (From Chen D, et al. Gasless single-incision laparoscopic appendectomy. *Surgical Endoscopy*. 2011;25:1473. Reprinted with permission from Springer Nature)

on internal rotation of the hip which can occur with a pelvic appendix. *McBurney's point* (■ Fig. 23.1) is located at one-third of the distance along an imaginary line drawn from the

anterior superior iliac spine to the umbilicus and marks the incision site for open appendectomies. *McBurney's sign* is maximal tenderness at McBurney's point.

Pathophysiology

What Explains the Transition From Periumbilical Pain to Right Lower Quadrant Pain in Appendicitis?

Autonomic nerves (sympathetic and parasympathetic) supply visceral peritoneum, while the parietal peritoneum has somatic innervation derived from spinal nerves. The visceral peritoneum senses pain when stretched or distended and results in dull, poorly localized pain associated with nausea and diaphoresis. Often in the early hours of appendiceal inflammation, only the visceral peritoneum is affected. The patient perceives a vague type of abdominal pain in the periumbilical region. In contrast, as the inflammation progresses, the parietal peritoneum becomes affected and results in a sharp, severe type of pain localized to the region of appendiceal inflammation at the right lower quadrant.

Is the Appendix Considered Foregut, Midgut, or Hindgut? And How Does that Influence Where the Visceral Pain in the Abdomen Is Perceived?

The appendix, along with the small bowel (distal to the ligament of Treitz), cecum, ascending colon, and 2/3 of the transverse colon are derived from the midgut. Pain in the midgut is primarily perceived in the periumbilical region. In contrast, pain in the foregut (esophagus to distal duodenum) is usually perceived in the epigastrium, and pain in the hindgut (left colon and rectum) is perceived in the hypogastrium (suprapubic).

Can Appendicitis Present with No Abdominal Pain?

Yes. In some cases, a *retrocecal appendicitis* may not cause any abdominal pain. If the appendix is completely separated from the anterior abdominal peritoneum, then the patient will not develop any localizing symptoms. However, irritation of adjacent structures can cause diarrhea, urinary frequency, CVA tenderness, pyuria, and microscopic hematuria, which may be the only clues.

Why Is Hyperesthesia of the Skin a Sign of Acute Appendicitis?

Parietal peritoneum is supplied by spinal nerves. With irritation of the parietal peritoneum, the area of skin supplied by the spinal nerves on the right at T10–12 can become very sensitive to touch, a phenomenon known as *cutaneous hyperesthesia*.

What Is a Closed-Loop Obstruction?

A closed-loop obstruction develops when a loop of bowel is obstructed at two points such that there is no outlet for the bowel contents and pressure. As pressure continues to build, the loop of bowel will continue to distend until venous pressure is exceeded followed by arterial inflow. With the blood supply to the loop compromised, ischemia and infarction ensue.

How Does a Closed-Loop Obstruction Pertain to Acute Appendicitis?

In acute appendicitis, a commonly accepted etiology involves obstruction of the proximal appendiceal lumen by a *fecalith* (in adults) or *lymphoid hyperplasia* (in children). Since the appendix is a blind loop, this creates a closed-loop obstruction. The appendiceal mucosa continues to secrete mucus. Resident bacteria in the appendix begin to multiply rapidly. Consequently, the appendix distends rapidly, and intraluminal pressure exceeds venous pressure. Vascular congestion ensues until arteriolar supply is compromised as well. Ischemia and gangrene occur first at areas with the poorest blood supply resulting in a weakened wall. Perforation eventually occurs at the antimesenteric border just beyond the point of obstruction where the tension is high. Increased luminal pressure alone is not directly responsible for the perforation.

What Are Some Other Examples of a Closed-Loop Obstruction?

Obstructing colon cancer with a functioning ileocecal valve, diverticulitis, incarcerated hernia, volvulus, acute cholecystitis, and Richter's hernia (only part of the circumference of the bowel wall is trapped within the hernia sac).

What Are Other Causes of Appendiceal Obstruction?

Other causes of appendiceal obstruction include inspissated barium (impacted bariolith) after radiological studies,

tumors (adenocarcinoma of the appendix), ingested seeds, and parasites (*Ascaris lumbricoides* most common).

Workup

What Are the Critical Laboratory Values Utilized in the Workup of Acute Appendicitis?

The most important is leukocytosis with a left shift. More recently, elevated C-reactive protein (CRP), a marker for inflammation, has been shown to be useful in the diagnosis of acute appendicitis. All women of childbearing age presenting with abdominal pain should receive a beta-hCG pregnancy test to rule out an ectopic pregnancy.

What Is the Significance of WBCs in the Urine Without Bacteria? How Might this Mislead the Clinician?

A few white blood cells can be seen in the urine (sterile pyuria) with appendicitis as a result of ureteral or bladder irritation by the inflamed appendix. This laboratory finding may mislead the clinician in believing the patient may have cystitis. However, bacteriuria (bacteria in urine) should not be present in catheterized urine specimen.

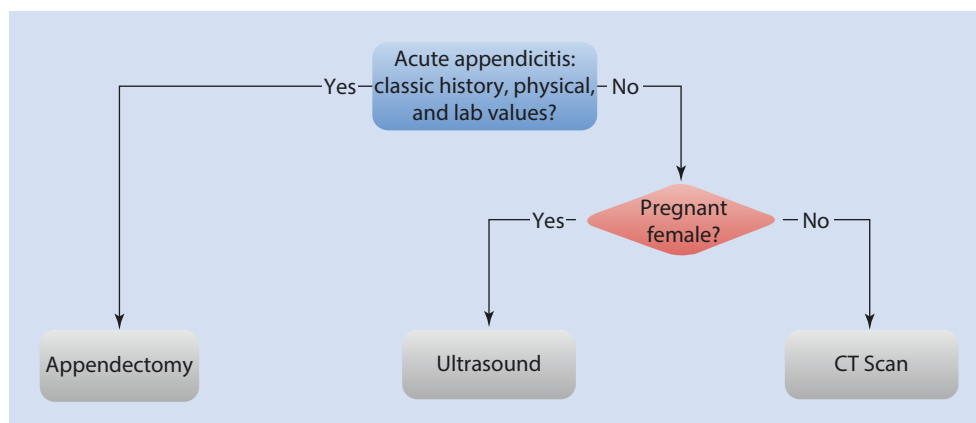
What Further Imaging Is Needed?

Given the classic presentation in an adult male, no further imaging is needed (■ Fig. 23.2).

When Would Imaging Be Indicated? How Should the Use of Imaging Studies Differ Between Adults and Kids? Men and Women?

In cases where the diagnosis is equivocal, ultrasonography or CT scan can be helpful. Ultrasound can identify a thick-walled, noncompressible tubular structure (dilated appendix)

■ Fig. 23.2 Algorithm for acute appendicitis



in the right lower quadrant. Peritoneal fluid and/or an abscess can sometimes be seen in advanced cases. Ultrasonography is particularly useful in women and children. In women, ultrasound is used to rule out gynecologic pathology such as ovarian torsion, tubo-ovarian abscess, or an ectopic pregnancy. Ultrasonography is used in children and pregnant women (MRI is another option in pregnancy), as the child and the fetus are more vulnerable to the effects of radiation. Also, because children have less periappendiceal fat, the appendix is not as readily visualized on CT scan. Thus, CT scan is utilized in adult men and nonpregnant women when the diagnosis is unclear. CT findings consistent with acute appendicitis include periappendiceal fat stranding and an enlarged appendiceal diameter >6 mm (■ Figs. 23.3 and 23.4).

Do Any Clinical Tools Exist to Help Decide if Acute Appendicitis Is Likely?

The Alvarado score is a 10-point system to help with the early diagnosis of acute appendicitis. This is most useful in pediatric cases and includes the classic migration of pain, anorexia, nausea/emesis, RLQ tenderness (McBurney's sign), rebound, fever, leukocytosis, and left shift. The two highest point allocations (2 points) are for RLQ tenderness and leukocytosis. However, the most reproducible and reliable finding in acute appendicitis is RLQ tenderness.



■ Fig. 23.3 Coronal CT showing the normal appendix (white arrow) as a thin tubular structure arising from the base of the cecum



■ Fig. 23.4 Coronal CT showing a dilated, thick-walled, fluid-filled appendix containing appendicoliths, indicating acute appendicitis. White arrows, dilated appendix; black arrows, appendicoliths

What Are the Radiographic Signs of Appendicitis?

Plain abdominal X-ray is generally not helpful in the diagnosis of acute appendicitis as there are no consistent and reliable findings. However, on occasion, a calcified fecalith will be seen in the RLQ, which is highly suggestive of appendicitis.

Management

What Is the Definitive Treatment for Appendicitis?

Surgical removal of the appendix (appendectomy) with either a laparoscopic or open approach.

Is Laparoscopic or Open Appendectomy the Superior Approach?

Both laparoscopic and open appendectomy approaches are effective treatments for acute appendicitis. Studies have shown that laparoscopic appendectomy results in slightly

decreased postoperative pain, shorter length of stay, decreased wound infection rate, and a faster return to normal activity. However, the duration of surgery is longer, and costs are higher with laparoscopy. Interestingly, the rate of postoperative intra-abdominal abscess may be higher with laparoscopic appendectomy. The decision over which approach to use is based on surgeon preference, patient characteristics, and patient preference. Presently, laparoscopic appendectomy is the preferred approach at most institutions.

What Is the Role of Pre- and Postoperative Antibiotics for Acute Non-perforated Appendicitis? For Perforated Appendicitis?

A single dose of preoperative antibiotics has been shown to reduce infectious complications and should be given to patients with both acute non-perforated and perforated appendicitis. In simple non-perforated appendicitis, antibiotics should not exceed 24 hours postoperatively. For perforated or gangrenous appendicitis, the duration of IV antibiotics is controversial, most recommend continuation until the patient's fever and leukocytosis have resolved which typically takes 3–5 days.

How Should You Proceed if You Are Performing a Laparoscopic Appendectomy and You Discover that the Appendix Appears to Be Normal? Do You Remove the Appendix Anyway? Are There Circumstances Where an Appendectomy Is Contraindicated?

The rate of finding a normal appendix during laparoscopic appendectomy (negative appendectomy) is roughly 10% and occurs more commonly in the elderly, infants, and young women. In general, the appendix should be removed at that point even though it does not appear to be inflamed. That way, if the patient develops RLQ pain in the future, acute appendicitis is effectively ruled out. It is also important to search (intraoperatively) for other causes that can mimic appendicitis (e.g., inflammatory bowel disease, Meckel's diverticulitis, pancreatitis, cholecystitis). In the case of regional enteritis (Crohn's) involving the cecum (as evident by inflammation/thickening of this area), the appendix should not be removed because of the high risk of developing an enterocutaneous fistula. Similarly, a biopsy should be avoided for the same reason, but the patient should be scheduled for a colonoscopy in 2–4 weeks. However, if the cecum does not appear to be inflamed, performing an appendectomy is the appropriate management.

Areas Where You Can Get in Trouble

All Patients

Misdiagnosing Appendicitis as Cystitis

Do not assume that sterile pyuria rules out appendicitis and therefore misdiagnose a patient who has appendicitis as cystitis and treat with oral antibiotics. Conversely, bacteruria (bacteria in urine) should not be present in catheterized urine specimen of a patient with appendicitis.

Misdiagnosing Other Causes of Perforation as Appendicitis

Any pathology that causes peritonitis (e.g., pelvic inflammatory disease, perforated ulcer) can cause the serosa of the appendix to get inflamed and lead to signs and symptoms suggestive of appendicitis. This is termed *periappendicitis*. If during surgery you see purulent fluid in the pelvis suggesting a perforated appendicitis, but then a non-perforated yet inflamed appendix is found, consider periappendicitis. Explore the abdomen carefully for another source for the peritonitis.

Pseudoappendicitis

Pseudoappendicitis refers to a disease which presents exactly like appendicitis but is due to another cause. The classic cause is a *Yersinia enterocolitica* infection which presents with RLQ pain, fever, vomiting, and bloody diarrhea. Patients may have sick contacts (e.g., teacher at daycare center). It is usually self-limited but in immunosuppressed patients can result in fatal sepsis. Treatment consists of doxycycline.

Women

Missing Ovarian Torsion: A Surgical Emergency

Right-sided ovarian torsion can be mistaken for acute appendicitis given similar symptoms such as RLQ pain, fever, and leukocytosis. Transvaginal ultrasound and/or CT scanning can help with diagnosis. Ovarian torsion is a surgical emergency, and delays can result in necrosis of the ovary. In fact, salvage of the ovary is only about 10% in adults, due to delays in diagnosis.

Misdiagnosing Ruptured Appendicitis as Pelvic Inflammatory Disease (PID)

Pelvic inflammatory disease can mimic ruptured appendicitis in that both can cause cervical motion tenderness and right adnexal tenderness. However, with PID, nausea and vomiting are less common. Additionally, the pain of PID is typically lower in the abdomen, in the bilateral lower quadrants from the onset, associated with a history of foul smelling vaginal discharge, and smear of vaginal discharge may show bacteria. It is important to inquire about risk factors for PID such as young age at first intercourse, unprotected intercourse,

history of PID or other sexually transmitted diseases, and multiple sexual partners. Transvaginal ultrasound and/or CT scan are helpful. PID is treated with antibiotics, whereas a ruptured appendicitis with diffuse peritonitis requires surgery.

Misdiagnosing Acute Appendicitis During Pregnancy

Acute appendicitis is the most common surgical emergency in pregnancy. Traditionally, the diagnosis was considered particularly challenging because it was believed that as pregnancy advances; the normal anatomic relations become distorted, leading to atypical pain in the upper quadrants as a result of a shifted appendix. Recent studies have confirmed that the majority of pregnant women with appendicitis report pain in the RLQ in all three trimesters. Delaying diagnosis can result in increased risk of perforation. The risk of fetal loss with perforated appendicitis is markedly increased when compared to without perforation. Similarly, the risk of premature delivery is significantly increased. Conversely, performing an appendectomy for a pregnant patient without true appendicitis is associated with fetal loss and premature delivery as well. Establishing an accurate and early diagnosis with either ultrasound or MRI is crucial.

Watch Out

Appendiceal perforation is the most significant risk factor for fetal mortality in a pregnant woman with acute appendicitis.

Extremes of Age

Under Age 5, Harder to Get History and Examine, and Are More Prone to Early Rupture

Diagnosis of appendicitis is challenging in young children due to their inability to give an accurate history and frequent GI upset. Children <5 years of age more often present with perforated appendicitis (45%), and their underdeveloped omentum is less capable of containing the rupture.

Elderly: More Prone to Rupture

Elderly patients tend to present later in their course of appendicitis, have an atypical presentation, and have a higher rate of rupture (>50%). The higher rate of morbidity and mortality associated with perforated appendicitis means that the index of suspicion for appendicitis should be higher in the elderly. Incidence of colon cancer increases with age. Perforated colon cancer can mimic appendicitis in the elderly. The presence of microcytic anemia should prompt workup for colon cancer.

Immunosuppressed Patient

Incidence of acute appendicitis is higher in patients with human immunodeficiency virus (HIV). Presenting symptoms are similar to non-infected patients; however, these patients manifest only relative leukocytosis. There is an increased risk of perforation secondary to low CD4 count and delay in

presentation. Also consider neutropenic enterocolitis (typhilitis) and opportunistic infections in the differential diagnosis. HIV is not a risk for adverse surgical outcomes.

Areas of Controversy

Is Appendicitis a True Surgical Emergency?

Traditionally, acute appendicitis warrants emergent operation to prevent perforation. However, the risk of rupture in adults was shown to be low in the first 36 hours with a 5% risk of rupture in each subsequent 12-hour period. Thus, appendicitis should be treated urgently but is not necessarily a true surgical emergency.

Can Acute Non-perforated Appendicitis Be Managed Nonoperatively?

For the present, the gold standard of care for acute appendicitis is surgical appendectomy. However, a number of recent studies have been published examining the outcomes of appendectomy versus antibiotics alone. The APPAC study was a randomized clinical trial demonstrating that outcomes in those treated with antibiotics alone for uncomplicated appendicitis were not any worse compared to those treated with appendectomy. The NOTA study was a 2-year follow-up study on patients with acute appendicitis managed nonoperatively and found the recurrence rate to be 14% and that recurrent episodes of RLQ pain could be safely managed with further antibiotics. And finally, in a study of over 230,000 appendicitis patients using a large California database, those managed nonoperatively had no difference in complications, mortality, or hospital costs, compared to those that underwent appendectomy. However, the hospital length of stay was longer.

Patients with Protracted History of Acute Appendicitis and a Palpable Abdominal Mass

If a patient has more than a 5-day history of RLQ pain, the appendix by then has most likely ruptured. When it ruptures, one of two things happen: (1) the infection spreads to cause diffuse peritonitis causing the patient to seek medical care or (2) the body, with the help of the omentum, walls off the perforation to create a localized abscess. An abscess may cause localized pain and vague pain or present with systemic symptoms (fever, tachycardia, leukocytosis). The next step is to confirm an intra-abdominal abscess with a CT scan and start broad-spectrum IV antibiotics. In the case of a large abscess (>5 cm), it is also treated with a percutaneous placed drain. This approach results in lower morbidity and mortality compared to immediate appendectomy but requires a longer hospital stay. The failure rate is 9–15%, and if it fails, operative intervention is required.

After Nonoperative Management of an Appendiceal Abscess, Is Interval Appendectomy Necessary?

Following successful nonoperative management of a perforated appendicitis with abscess, performing an interval appendectomy (performing appendectomy 6–8 weeks later) to prevent a future attack is controversial. The lifelong risk of appendicitis is 7–9%. As such, the majority of experts' opinion is that interval appendectomy is unnecessary. Oftentimes, at interval appendectomy, the residual appendix is scarred and involuted.

Summary of Essentials

History

- Anorexia (hamburger sign), nausea, vomiting
- Vague periumbilical pain that shifts to the RLQ

Physical Exam

- McBurney's point tenderness
- Cutaneous hyperesthesia and Rovsing's, psoas, and obturator signs

Laboratory

- Elevated WBC with left shift
- C-reactive protein
- Pregnancy test
- Urinalysis: sterile pyuria

Diagnosis

- Oftentimes is a clinical diagnosis

Imaging

- None needed with classic H&P and leukocytosis
- US: women and children
- Avoid CT in children (increased risk of malignancy) and pregnancy (risk to fetus)
- CT: if diagnosis is equivocal in men and nonpregnant women
- MRI: pregnant women

Pathophysiology

- Closed-loop obstruction
- Fecalith in adults, lymphoid hyperplasia in children

Management

- Appendectomy (open or laparoscopic)

Special Situations

- Abnormal urinalysis does not rule out an appendicitis.
- CT is the most sensitive test for appendicitis and may show fecalith, periappendiceal fat stranding, free fluid, or phlegmon.
- Perforated appendicitis is a result of a closed-loop obstruction creating an ischemic mucosal wall and not a direct result of increased intraluminal pressure.
- Most common cause of appendicitis is fecalith in adults, and lifetime incidence of acute appendicitis is 6–7%.
- Consider pseudoappendicitis in a patient with history suggestive of appendicitis + extensive diarrhea.

Suggested Reading

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Pencil-Thin Stools and Intermittent Constipation

Areg Grigorian, Christian de Virgilio, Tracey D. Arnell, and Beverley A. Petrie

Case Study

A 57-year-old obese man with diabetes is seen by his primary care physician for his yearly physical. He endorses a 20-lb weight loss in the past few months without changing his diet or exercise. He also reports pencil-thin stools and intermittent constipation. He

feels that he cannot adequately evacuate his stool. There is no blood or mucus in his stool. He has a 20 pack-year smoking history. He has never had a colonoscopy. Family history is negative for any cancer. On exam, he is afebrile with a heart rate of 78/min and blood

pressure of 132/74 mmHg. His abdomen is soft and non-tender. No abdominal masses are palpated, and he is non-distended. On rectal exam, he has no masses and no gross blood. Laboratory examination reveals a hematocrit of 37% (normal 40–52%).

Diagnosis

What Is the Differential Diagnosis for a Change in Bowel Habits?

What Is the Most Likely Diagnosis?

Given the patient's bowel symptoms, anemia, weight loss, and age, the most likely diagnosis is colon cancer until proven otherwise. His predominant symptoms are those of a slowly

Table 24.1

Condition	Change in bowel habits	Other characteristics
<i>Colorectal cancer</i>	Diarrhea, constipation, decreased stool caliber (left colon)	Iron deficiency anemia (more right colon), fatigue, weight loss, bright red blood per rectum (rectal cancer)
<i>Irritable bowel syndrome (IBS)</i>	Diarrhea alternating with constipation, +/- mucus, no blood	Symptom-based diagnosis, chronic abdominal pain relieved by BM, bloating, tenesmus, depression/anxiety common
<i>IBD (ulcerative colitis or Crohn's)</i>	Diarrhea +/- blood, mucus	Abdominal pain, severe cramps, weight loss, anemia
<i>Celiac disease</i>	Pale, loose, and greasy stool (steatorrhea), diarrhea	Weight loss, failure to thrive (in children), malabsorption, anemia, <i>dermatitis herpetiformis</i> (autoimmune maculopapular rash)
<i>Intestinal pseudo-obstruction (Ogilvie's)</i>	Constipation	Bowel distention (especially cecum) in the absence of anatomic lesions, severely ill hospitalized patients, nausea, vomiting, electrolyte imbalance, opioid use
<i>Thyroid disease</i>	Diarrhea (hyperthyroid) or constipation (hypothyroid)	Anxiety, tremor, palpitations, heat intolerance with hyperthyroidism; fatigue, cold intolerance with hypothyroidism
<i>Drugs (laxatives, antidiarrheal)</i>	Diarrhea or constipation	Medication-induced change in bowel habits, <i>melanosis coli</i> , weight loss, psychosocial comorbidities
<i>Infectious</i>	Diarrhea	Viral, bacterial, or parasitic infection

BM bowel movement, IBD inflammatory bowel disease

obstructing lesion as evidenced by a change in bowel habits with pencil-thin stools, which is most suggestive of a left-sided lesion.

Screening

What Screening Is Recommended for Colorectal Cancer?

The US Preventive Services Task Force (USPSTF) recommends screening in all adults of average risk, beginning at age 50 until age 75. The decision to screen individuals between 76 and 85 is made on an individual basis, whereas screening is not recommended for individuals over age 85.

What Screening Is Recommended for Colorectal Cancer in Patients with a First-Degree Family Member with Colorectal Cancer? How About for IBD?

These patients should begin screening at age 40 or 10 years prior to the onset of colorectal cancer in the first-degree relative, whichever comes first, if the relative was less than 60 when diagnosed. They should continue screening every 5 years after. Patients with IBD should undergo screening 8–10 years after the diagnosis of IBD. If primary sclerosing cholangitis was the presenting symptom for IBD, a screening colonoscopy should be performed at that time.

Table 24.2 Screening for colorectal cancer

Screening	USP-STF	Interval	Features
Colonoscopy	Yes	Every 10 years	Visualizes the entire rectum and colon, can detect lesions less than 0.5 cm, able to remove polyps and obtain biopsies, used as a follow-up test if other tests are equivocal, sedation required, 0.2% perforation risk
Fecal occult blood test (FOBT) Fecal immunochemical test (FIT) Stool DNA (FIT-DNA)	Yes Yes Yes	Annually Annually Every 1–3 years	Traditional hemoccult chemical test (requires dietary modifications 3 days prior) and newer fecal immunochemical test and stool DNA (both with greater sensitivity), can be done at home, positive test requires colonoscopy
Flexible sigmoidoscopy	Yes	Every 5 years	Limited to only the lower third of the colon, able to remove polyps and obtain biopsies, sedation required; if abnormal, must undergo colonoscopy
CT colonography	Yes	Every 5 years	As likely as colonoscopy to detect lesions 10 mm or larger but may be less sensitive for smaller adenomas, requires bowel prep, does not require sedation, may identify incidental findings (i.e., extracolonic neoplasms or AAA), and does not allow for biopsy or polypectomy

What Are the Differences Between the Various Screening Modalities?

The decision to use a particular screening tool needs to be made by the patient after discussing the benefits, risks, and financial considerations imposed on the patient. [Table 24.2](#) goes over the key differences.

Watch Out

Diets rich in red meat can result in a false-positive fecal occult blood test (FOBT) test.

History and Physical

What Is the Significance of the Patient's Unintended Weight Loss?

Unexplained weight loss is a cause for concern because it may suggest malignancy. In patients with colorectal carcinoma, it may signify disseminated disease. Although the pathogenesis of cancer-related cachexia is not fully understood, *TNF- α* seems to play a central role and has direct catabolic effects on skeletal muscle. Other causes of unexplained weight loss include depression, celiac disease, Addison's disease, chronic obstructive pulmonary disease, IBD, peptic ulcer disease, tuberculosis, and hyperthyroidism.

What Are the Risk Factors for Colon Cancer?

The risk factors for colon cancer include older age (majority are over 50), black race, IBD, family history, low-fiber/high-

fat diet, sedentary lifestyle, obesity, smoking, alcohol, and type 2 diabetes.

Where Does Colon Cancer Rank in Terms of the Most Common Cancers in the USA? In Terms of the Highest Overall Mortality?

Table 24.3

	Incidence (in order of frequency)	Mortality (highest first)
Men	Prostate, lung, and colon	Lung, prostate, and colon
Women	Breast, lung, and colon	Lung, breast, and colon

Are Right- or Left-Sided Colon Cancers More Common, and How Do the Presentations Differ?

The majority of colon cancers are left sided and occur near the rectosigmoid junction. Left-sided colon cancers are more likely to cause a change in bowel habits and symptoms of obstruction. When stool reaches the sigmoid, it is often hard and devoid of excess fluid. The caliber of the lumen is also narrower on the left side, and with a circumferential tumor causing partial obstruction, patients report pencil-thin stools, often tinged with blood. Bowel habits can alternate between constipation and diarrhea. Patients report distention with lower abdominal colicky pain. Patients with lesions

that are closer to the anal orifice may report bright red blood per rectum (hematochezia). A smaller number of colon cancers are right sided, and the most common finding is an insidious onset of iron deficiency anemia secondary to chronic GI blood loss. Rarely, if the tumor is rapidly growing, patients can experience severe pain, and a RLQ mass may be appreciated on exam.

Watch Out

Melena is more common in right-sided colon cancers.

Why Is the Rectal Examination Important in Suspected Colorectal Cancer?

The digital rectal exam (DRE) is often overlooked by the novice, yet it is of critical importance in the evaluation of a patient with possible colorectal cancer. A DRE by itself is not a good test for detecting colon cancer because its reach is limited. However, the value of the DRE lies in its ability to detect low rectal cancers because it allows the examiner to feel a mass, which is suggestive of malignancy. In addition, distance from the anal verge, mobility, and anatomic relation to other pelvic structures can be assessed. A fixed mass is more likely to be locally advanced, and relation to the prostate, vagina, and sacrum is important for surgical planning.

Pathophysiology

What Is a Polyp, and How Are They Generally Classified?

A polyp is a mass that protrudes into the lumen of the GI tract and can either be pedunculated (with a stalk) or sessile (flat). Nonneoplastic polyps can arise from abnormal mucosal maturation, inflammation, or colonic architecture. However, polyps arising from epithelial proliferation and dysplasia are true neoplasms and may have malignant potential. They are collectively known as adenomatous polyps or adenomas.

Watch Out

Juvenile polyposis syndrome can result in a large number of hamartomatous polyps in the stomach and colon occurring in children. Multiple hamartomatous polyps alongside with mucocutaneous hyperpigmentation spots on the lips and genitalia are concerning for *Peutz-Jeghers syndrome*.

What Is the Difference Between Hyperplastic and Hamartomatous Benign Polyps?

Table 24.4

Type	Features
<i>Hyperplastic</i>	Small (<5 mm in diameter) and smooth; the most common type of polyp; isolated polyps are typically benign; it is now recognized that there are hyperplastic polyposis syndromes in which there may be a risk of malignancy
<i>Hamartomatous</i>	Rounded, smooth, and sometimes have a stalk (<2 cm); occur most commonly in children (<5 years); usually present as a solitary rectal polyp that prolapses

How Do Colon Cancers Develop?

The majority of colon cancers arise from the adenoma-carcinoma sequence (■ Fig. 24.1). This is also known as the chromosome instability pathway since there is a stepwise accumulation of mutations leading to carcinoma. The sequence begins with a loss of the APC tumor suppressor gene resulting in decreased intercellular adhesion and increased proliferation. A subsequent KRAS mutation achieves unregulated intracellular signaling and transduction which allows for the formation of an adenoma. Adenomatous polyps are considered premalignant, and it is estimated that 20% will go on to become malignant. The malignant potential of an adenomatous polyp is related to the age of the patient, the size of the polyp, and the villous component. Finally, loss of the p53 tumor suppressor gene will increase tumorigenesis in an adenoma and result in carcinoma. In a smaller number of colon cancers, microsatellite instability plays a bigger role in which impaired DNA mismatch repair enzymes are unable to ensure the fidelity of a copied DNA strand, increasing the risk for developing cancer.

What Features of an Adenoma Are Associated with an Increased Malignant Risk?

There are four subtypes of adenomas (■ Table 24.5) that are based on their epithelial architecture. Their risk of malignancy is dependent on polyp size, architecture, and severity of dysplasia. Larger adenomas are more ominous with a 40% chance of cancer in adenomas > 4 cm. Disarrangements in architecture and severe dysplasia can also increase the risk of cancer.

Fig. 24.1 Adenoma-carcinoma sequence (From Chu DZJ, et al. The Surgeon's Role in Cancer Prevention. The Model in Colorectal Carcinoma. *Annals of Surgical Oncology* 2007;14(11):3058. Reprinted with permission from Springer Nature)

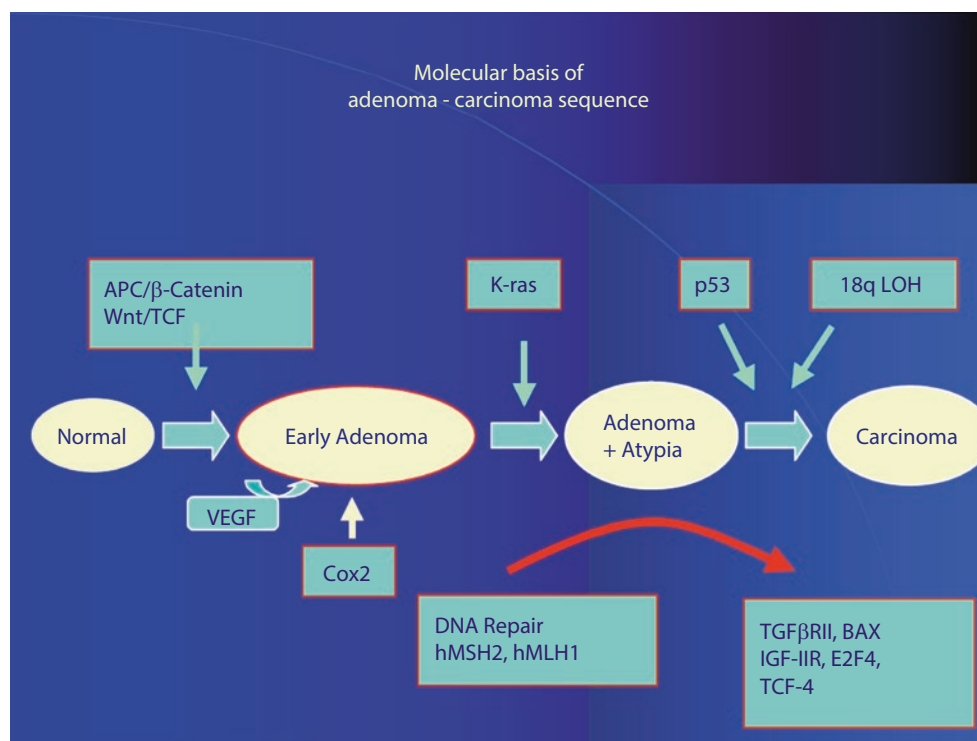


Table 24.5 Adenoma subtypes

Adenoma type	Features
Tubular	The <i>most common type</i> with the majority occurring in the rectosigmoid but can be found anywhere in the colon
Villous	Less common than tubular; tend to be larger and occur in older persons, typically in the rectum; more commonly sessile, and with cauliflower-like projections; high malignant potential
Tubulovillous	Composed of both tubular and villous features; can be pedunculated or sessile
Sessile serrated	Flat, broad-based polyps that can be mistaken for hyperplastic polyps; have high malignant potential; have a "sawtooth" appearance under the microscope

Why Screen Every 10 Years When Using Colonoscopy?

The majority of adenocarcinomas arise from adenomatous polyps. Observational studies have suggested that the sequence from adenoma to carcinoma takes about 10 years. Visualizing the entire colon with a colonoscopy every 10 years is sufficient to catch the majority of these cancers. In patients with other risk factors, screening may need to occur more frequently.

Why Is Colonoscopy Superior to Flexible Sigmoidoscopy for Screening?

Flexible sigmoidoscopy is only able to visualize the rectum and the distal third of the colon, so polyps in the proximal colon will be missed. A complete colonoscopy is defined by the endoscope reaching the cecum and visualizing the ileocecal valve. Thus, colonoscopy can adequately visualize the entire colon.

Where Are the Most Common Metastatic Sites for Colorectal Cancer?

Regional metastases are to the mesenteric lymph nodes (the N in the TNM system). The *liver* is the most common location of distant metastasis, owing to the venous drainage of the colon to the liver via the mesenteric veins draining to the portal system and the tendency for these cancers to spread hematogenously. Rectal cancers may have atypical locations for metastasis because they drain into the portal and systemic venous circulations. They first metastasize to the *lungs* because the inferior rectal veins drain into the inferior vena cava via the internal iliac veins. Via the systemic veins, rectal cancers may also metastasize to the inguinal lymph nodes. Additionally, via sacral veins, rectal cancers may result in spine and brain metastasis. Other locations for metastasis include the peritoneum, supraclavicular lymph node, and bones.

Watch Out

The most common site of metastasis for colon cancer is the liver, whereas the most common site for rectal cancer is the lung.

Watch Out

Individuals with first-degree family members with FAP should begin screening with a flexible sigmoidoscopy by age 10.

Watch Out

FAP needs to be ruled out prior to establishing a diagnosis of Lynch syndrome.

What Is the Relationship of Colon Cancer with Lynch Syndrome?

Hereditary nonpolyposis colorectal cancer (HNPCC) or Lynch syndrome is an autosomal dominant condition associated with multiple malignancies. The most common types are colorectal and endometrial, while the less common types are ovarian, stomach, breast, small bowel, pancreatic, kidney, and bile duct cancers. Lynch type 1 is caused by a heterozygous mutation in DNA mismatch repair genes and results in more colonic cancers, often on the right side and typically in the fourth decade of life. Lynch type 2 is caused by mutations in the MLH1 gene and results in more extracolonic cancers. Colon cancers associated with HNPCC still arise from adenomas, but the adenomas tend to be flat as opposed to polypoid. Also, the adenomas associated with HNPCC are more likely to become malignant than adenomas not associated with HNPCC, and this process takes place more rapidly than sporadic colorectal cancers.

What Are the Modified Amsterdam Criteria for HNPCC?

They are diagnostic criteria to help clinicians identify families that are more likely to have Lynch syndrome. The 3-2-1-0 rule can help you remember the requirements:

- 3 or more relatives with histologically verified cancers in the colon, endometrium, small intestine, or pelvis
- 2 or more successive generation affected
- 1 or more relatives diagnosed prior to age 50
- 1 should be a first-degree relative of the other two
- 0 familial adenomatous polyposis

What Is the Relationship of Colon Cancer with Familial Adenomatous Polyposis?

Familial adenomatous polyposis (FAP) is an autosomal dominant condition in which patients develop hundreds to thousands of polyps in the colon, which if left untreated, will develop into cancer. The mutation is in the adenomatous polyposis coli (APC) gene on chromosome 5 (remember, five letters in colon). Polyps begin on average in the mid-teens but can appear as early as age 7. Screening with flexible sigmoidoscopy should begin at age 10. Prophylactic colectomy is often recommended by age 20 to prevent the development of cancer. If left untreated, 100% of patients develop cancer by the fourth or fifth decade of life.

What Are the Two Variants of FAP?

Gardner's syndrome is an autosomal dominant condition with variable penetrance, characterized by osteomas and colonic polyps. If left untreated, all patients develop colon cancer by the fourth or fifth decade of life. *Turcot syndrome* is characterized by café au lait spots, malignant brain tumors (often glioblastoma multiforme), and neoplastic colon polyps that progress to cancer.

Watch Out

FAP patients are also at risk for the development of adenomas throughout the GI tract, particularly the duodenum with a malignant transformation such as periampullary carcinoma. As such, FAP patients should undergo surveillance with upper endoscopy every 1–3 years starting at age 25.

What Is the Difference Between Synchronous and Metachronous Tumors?

A synchronous tumor is a second primary cancer (nonmetastatic) that is present at the time of initial diagnosis or within the first 6 months. For this reason, it is important to examine the entire colon via colonoscopy, even if a colon cancer is discovered in the sigmoid colon. Metachronous tumors are primary cancers that develop elsewhere in the colon at least 6 months after the primary resection. This should be distinguished from recurrent cancer, in which the colon cancer returns at the margins of the surgical resection in the colon or mesentery.

Workup

For the Patient Described Above, What Would Be the Next Steps in the Workup?

Given that the patient is manifesting symptoms that are highly concerning for colon cancer, colonoscopy is recommended, with biopsy of any suspicious lesions.

Is There Any Role for Testing His Stool for Blood?

In the case presented, there is sufficient suspicion for colon cancer and thus a strong indication for additional workup, such that testing for blood in the stool is not important. An error would be to test the stool for blood and, if negative, assume there is no colon cancer. Additionally, any patient presenting with the complaint of rectal bleeding should not have a hemoccult test performed as bleeding from all sources can be intermittent, and thus, the test may be a false negative. Evaluation should be based on their complaint.

Once a Diagnosis of Colon Cancer Is Established, What Laboratory Tests Are Recommended?

Carcinoembryonic antigen (CEA) level and liver enzyme tests are recommended. Elevation of liver enzymes (particularly alkaline phosphatase) is suggestive of possible liver metastasis.

Is CEA Useful for Screening? How Is It Used?

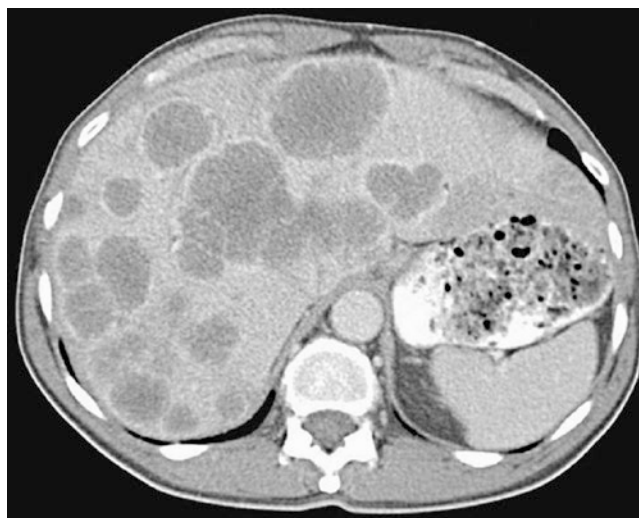
No. The low specificity and sensitivity of CEA make this an inaccurate screening tool for colorectal cancer. A very high CEA level at diagnosis is suggestive of metastatic disease. Primarily, CEA level is used as a marker for successful treatment and to detect recurrence. A drop in CEA level following surgery is indicative of success of the intervention. However, not all patients with colorectal cancers have an elevated CEA level. After surgery, it is recommended to check the CEA every 3 to 6 months for the first 2 years to monitor for recurrence, but this should not be the sole method for disease recurrence. A physical exam and CT scan should be performed in 6 months.

What Other Conditions Can Elevate the CEA Level?

Gastritis, peptic ulcer disease, hepatic disease, pulmonary disease (i.e., COPD), diabetes, visceral cancers (e.g., gastric or pancreatic cancers), IBD, chronic inflammatory conditions (e.g., rheumatoid arthritis), and smoking can elevate the CEA level.

What Additional Imaging, if Any, Is Recommended Once a Diagnosis of Colon Cancer Is Established?

CT scans of the chest, abdomen, and pelvis are recommended to detect metastasis. Nearly 20% of patients initially present with metastatic spread. CT of the abdomen and pelvis may



■ Fig. 24.2 Axial CT of hypoenhancing liver masses consistent with metastases

identify distant metastasis to the liver (■ Fig. 24.2). Its sensitivity and specificity for regional lymph nodes are poor. Additionally, the primary tumor may be visualized, and its relationship to surrounding structures, including possible extracolonic invasion, can be evaluated. Chest imaging is done to look for pulmonary spread of disease. Routine use of PET scan does not add significant information and as such is not recommended.

How Is the Workup of Colon and Rectal Cancers Different?

As compared to colon cancer, there is more at stake with rectal cancer in terms of preserving the sphincter muscles and thus fecal continence, when planning a resection. The rectum is in a confined space, so there is also less room for the surgeon to work in terms of getting adequate lateral and distal resection margins. As such, with rectal cancer, it is imperative to determine if the cancer has spread outside the confines of the rectal wall and how close the tumor is to the sphincter muscles. Such information helps select patients that are appropriate candidates for sphincter-preserving surgery as well as those that may benefit from neoadjuvant therapy to shrink the tumor prior to surgery so as to make it more resectable later. For these reasons, transrectal ultrasound (TRUS) and MRI are obtained with rectal cancer. TRUS and MRI have been shown to have improved staging ability when compared to CT and physical exam in terms of local staging (tumor depth and involvement of adjacent organs in T stage). Locally advanced tumors as those with suspected mesenteric node involvement generally undergo chemotherapy and radiation prior to surgery (neoadjuvant). This has been shown to downstage and shrink tumors, increasing the chance for sphincter preservation, decrease local recurrence rates, and improve disease-free survival.

Watch Out

Adjuvant therapy is a planned addition of therapeutic agents (i.e., chemotherapy, radiation, hormone therapy) following surgery in an attempt to treat advanced disease. *Neoadjuvant therapy* is administered prior to surgery and often done to shrink or debulk tumors to make resection more amenable. *Salvage therapy* is an unplanned addition employed when standard therapy fails.

How Do You Stage Colon Cancer?

The most commonly used staging system is the one described by the American Joint Committee on Cancer (AJCC). *T* (tumor) describes the size of the tumor and/or its depth of invasion. *N* (node) describes spread to regional lymph nodes. *M* (metastasis) indicates if the tumor has metastasized remotely.

Management

How Are Polyps that Are Found During Colonoscopy Managed?

Polyps can be removed with polypectomy and surveyed 1–5 years after for recurrence depending on the number and size of polyps. Any identified polyp must be removed in its entirety. If this cannot be done endoscopically, segmental surgical colonic resection is warranted.

What Is a “Bowel Prep,” and Why Is It Done?

A “bowel prep” essentially prepares the colon for surgery. The premise behind it is that it removes all stool from the colon, theoretically preventing stool spillage into the peritoneum when the colon is divided at surgery. For colonoscopy, it permits better visualization of polyps. Most bowel preps consist of orally ingested polyethylene glycol that the patient drinks on the day prior to the procedure. Some clinicians also use an oral nonabsorbable antibiotic prior to surgery to decrease colonic bacterial levels.

Watch Out

Bowel prep should not be utilized in patients suspected of having an obstructing cancer.

What Are the Recommended Operations in Colon Cancer?

The location (Table 24.6) of the primary cancer is the main determinant for what procedure is most appropriate.

Table 24.6 Location of colon cancer and procedure

Location of cancer	Operation
<i>Right-sided colon</i>	Right colectomy with ligation of the ileocolic artery
<i>Transverse colon</i>	Extended right colectomy with ligation of the ileocolic and middle colic artery
<i>Descending colon</i>	Left colectomy with ligation of IMA
<i>Sigmoid colon</i>	Left colectomy with ligation of IMA
<i>IMA inferior mesenteric artery</i>	

Watch Out

Intraoperatively, the large bowel can be identified by the taenia coli (longitudinal white line) and taenia epiploica (fat appendages). Taenia appears to splay out when the colon becomes the rectum. In contrast, the small bowel does not have these features and is much smoother than the large bowel.

What Operations Are Typically Offered to Patients with Rectal Cancer?

If the tumor is more than 2 cm proximal to the dentate line, a low anterior resection (LAR) is performed. LAR is done by removing part of the rectum through the abdomen and reconnecting the proximal colon with the distal rectum. If the tumor is within 2 cm of the dentate line, an abdominoperineal resection (APR) is more likely to be needed. An APR involves removing the entire distal rectum and anus including the sphincters, leaving a permanent colostomy.

How Many Lymph Nodes Should Be Resected?

A minimum of 12 lymph nodes should be resected, allowing for more accurate staging and improved prognosis.

Why Is Neoadjuvant Therapy Used for Rectal Cancer and Not Colon Cancer?

The goal of neoadjuvant therapy is to shrink the tumor so as to make it more amenable to a surgically curative resection and sphincter preservation. Because the rectum resides in a narrow space, resectability is more of an issue with rectal cancer than colon cancer. Thus, neoadjuvant therapy may shrink the rectal tumor sufficiently enough to allow for a curative resection, potentially decreasing local recurrence, and may spare the patient from needing a permanent colos-

tomy (APR). Both radiotherapy and chemotherapy (chemoradiation) are recommended because chemotherapy makes the cancer cells more sensitive to radiation. Neoadjuvant therapy is rarely used in early-stage colon cancer, as most colon cancers are surgically resectable. Postoperative chemotherapy is beneficial particularly in colon cancer patients with locally advanced disease and/or positive lymph nodes. It may be considered in patients diagnosed with metastatic disease at the time of presentation.

Why Is Radiation Used for Rectal Cancer and Not Colon Cancer?

Both types of cancers are radiosensitive, but radiation therapy is not feasible for colon cancer. To effectively irradiate the colon, the entire abdomen and/or pelvis would need to be irradiated. This would also irradiate the small bowel which is more vulnerable to acute radiation enteritis (manifested by persistent nausea, vomiting, abdominal cramping, fecal urgency, and watery diarrhea) as well as chronic radiation enteritis. The incidence of radiation enteritis and its chronicity increase as the dose of radiation and the percentage of normal bowel treated increase. The targeted field of radiation for rectal cancers is much smaller, making this complication less likely to occur.

What Are the Major Complications Specific to Colon Surgery?

Injury to the ureters (with either right or left colectomy), duodenum (during right colectomy), or spleen (during left colectomy) and anastomotic leak are the major complications specific to colon surgery. Careful dissection and identification of structures during surgery is important for avoiding intraoperative injuries. Approximately 6% of patients will develop an anastomotic leak which usually manifests in the first week after surgery with fever, abdominal pain and tenderness, ileus, and leukocytosis. In some cases, *tachycardia* may be the only presenting symptom of an anastomotic leak. Depending on the patient's clinical status, this may require urgent return to the operating room for exploration or additional imaging such as a CT scan. Patients with clinical signs of infection and a confirmed anastomotic leak should be taken to the operating room for exploration, washout, and ostomy diversion. Wound infections occur in as many as 25% of patients and generally only require opening the incision to allow drainage of the infection.

Areas of Controversy

Treatment of Stage-IV (metastatic) Colon Cancer

For patients with stage-IV colon cancer, there has been debate as to whether the appropriate primary treatment is

surgery with chemotherapy or chemotherapy alone. Recent studies have shown that resecting the primary tumor combined with chemotherapy drugs will lead to improved survival when compared to chemotherapy alone.

Is It Useful to Follow CEA Levels After Surgery?

According to the recommendations made by the National Comprehensive Cancer Network (NCCN) Guidelines 2018, it is recommended to check CEA levels every 3 to 6 months for 2 years following surgery. If normal, then repeat every 6 months for 3 years.

Summary of Essentials

History and Physical

- Change in bowel habits, weight loss, and anemia in an adult are indicative of colon cancer until proven otherwise.
- Right-sided colon cancer classically present with iron deficiency anemia; left-sided colon cancer present with obstructive symptoms (pencil-thin stools, constipation) and rectal cancer with hematochezia.
- Colon cancer is the third most frequent cause of cancer-related deaths in men and women.

Screening

- Colonoscopy every 10 years between ages 50 and 75.
- Screening should begin at age 40 or 10 years prior to onset of colorectal cancer in first-degree relative (if relative <60 years old).

Pathophysiology

- Polyps arising from epithelial proliferation and dysplasia (adenomatous polyps) have true malignant potential.
- Hyperplastic polyps are the most common type and almost always benign.
- Adenoma-carcinoma sequence is primarily responsible; microsatellite instability is less so.
- Lynch syndrome, FAP, Gardner's syndrome, and Turcot syndrome are inheritable conditions of colon cancer.

Diagnosis

- Diagnosis confirmation involves colonoscopy and tissue biopsy of suspicious lesions

Workup

- No role for hemoccult test with history highly suspicious for colon cancer
- CEA used as adjunct to other modalities to look for tumor recurrence; no screening role
- Colon cancer
 - CT scans of chest, abdomen, and pelvis
- Rectal cancer
 - MRI or TRUS
 - CT scan of chest, abdomen, and pelvis

Management

- Benign polyps
 - Polypectomy and reassessment in 1–5 years
- Colon cancer.
 - Right and/or left colectomy
 - Bowel prep prior to colectomy
 - Postoperative chemotherapy for locally advanced disease and/or positive lymph nodes
- Rectal cancer
 - APR for tumor within 2 cm of dentate line; LAR for proximal rectal cancer (> 2 cm proximal to dentate line)

Complications

- Right colectomy
 - Injury to the ureters
 - Injury to the duodenum
 - Anastomotic leak

- Left colectomy
 - Injury to the ureters
 - Injury to the spleen
 - Anastomotic leak

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Chronic Constipation Presenting with Severe Abdominal Pain

Beverley A. Petrie and Tracey D. Arnell

Case Study

An 80-year-old black male presents with severe abdominal distention and no bowel movement or gas per rectum for 3 days, as well as recent onset of vomiting. He has Parkinson's disease and chronic constipation and lives in a nursing home. His medications include levodopa and benztropine, which he has been taking for several years. His temperature is 37 °C, heart rate 90/min, blood pressure 116/70 mmHg, and respiratory rate 22/min. He appears to be tachypneic but otherwise nontoxic, with mental status unal-

tered from his baseline. Lungs are clear to auscultation bilaterally. His abdomen is severely distended. He does not have any abdominal surgical scars. He is tympanitic but has no significant tenderness to palpation. There are no palpable hernias, and rectal exam demonstrates an absence of stool and no palpable masses or strictures. Laboratory tests include metabolic panel with BUN 26 mg/dL (normal 7–21 mg/dL), creatinine 1.4 mg/dL (0.5–1.4 mg/dL) and electrolytes within normal limits, white blood cell

(WBC) $6.8 \times 10^3/\mu\text{L}$ ($4.1\text{--}10.9 \times 10^3/\mu\text{L}$), lactate 0.9 mmol/L (0.5–2.2 mmol/L), and arterial blood gas (ABG): pH 7.48// PaCO_2 30// PaO_2 80// HCO_3^- 24// SpO_2 99%. A plain upright abdominal radiograph shows a massively dilated loop of sigmoid colon with the apex pointing toward the right upper quadrant, consistent with the “coffee bean” or “bent inner tube” sign; upright chest radiograph shows no free air under the diaphragm.

Diagnosis

What Is the Differential Diagnosis?

Table 25.1

	Pathophysiology	Comments
<i>Colon cancer</i>	Mass causes mechanical LBO	History of weight loss; change in bowel habits, bloody stools
<i>Volvulus (sigmoid or cecal)</i>	Twisting of colon causes mechanical LBO	Sigmoid in elderly patients; debilitated or institutionalized patients with chronic constipation
<i>Diverticulitis (acute or chronic)</i>	Severe bowel wall edema may lead to LBO	Acute diverticulitis: pain and tenderness in LLQ
<i>Stricture</i>	Inflammation and scarring cause colonic narrowing	IBD, chronic diverticulitis, malignancy, abdominal/pelvic radiation; endoscopy can help identify cause
<i>Fecal impaction</i>	Inspissated stool in rectum or sigmoid causes mechanical LBO	Firm stool in rectal vault on exam
<i>Ogilvie's syndrome (pseudo-obstruction)</i>	Marked colonic distention without mechanical cause can lead to perforation	Debilitated, hospitalized patients, electrolyte imbalances, may decompress with neostigmine or colonoscopy
<i>Small bowel obstruction</i>	Most common cause in the USA is adhesions from prior surgery; hernias #1 worldwide	Nausea, extensive vomiting, abdominal surgical scar, hernia bulge
<i>Toxic megacolon</i>	Transmural infection of a markedly dilated colon, associated with ulcerative colitis, pseudomembranous colitis, other bacterial colitis	High fever, tachycardia, abdominal tenderness, acidosis, leukocytosis

IBD inflammatory bowel disease, LBO large bowel obstruction, LLQ left lower quadrant

What Is the Most Likely Diagnosis?

The massive, slowly progressive abdominal distention, combined with obstipation, and x-ray findings are consistent with a large bowel obstruction (LBO). The radiologic appearance is most consistent with a sigmoid volvulus.

History and Physical

What Is the Difference Between Obstipation and Constipation?

Constipation implies infrequent stools (<3 per week), usually associated with hard stools. Obstipation implies a *complete*

absence of gas or stool per rectum, which is highly suggestive of a bowel obstruction.

What Are the Classic Physical Exam Findings in Bowel Obstruction?

The presence of fever or tachycardia in association with an intestinal obstruction suggests strangulation with bowel ischemia or perforation. Tachypnea is common with LBO as diaphragm excursion is impaired. On abdominal exam, check for irreducible hernias (leading cause of SBO worldwide). In uncomplicated bowel obstruction, tenderness is generally lacking. The abdomen may be distended and tympanitic. A rectal exam must be performed to rule out fecal impaction, rectal neoplasm, or stricture.

What Clues on History and Physical Examination Help Distinguish Between Small and Large Bowel Obstruction

Small bowel obstruction (SBO) tends to be associated with more pronounced, and earlier onset, vomiting. In an early SBO, bowel sounds are hyperactive, with “rushes and tinkles” (high-pitched sounds of hyperperistaltic small bowel). LBO is more likely to be associated with more pronounced distention, less or late-onset vomiting, and decreased bowel sounds.

Why Is a History of Neurologic or Psychiatric Disorders Important?

Drugs used to treat neurologic (such as Parkinson’s) or psychiatric diseases can affect colonic motility and predispose to chronic constipation, elongation of the sigmoid, and volvulus, as well as colonic pseudo-obstruction.

Watch Out

The most common *symptom* of sigmoid volvulus is lower abdominal pain. The most common *sign* is abdominal distention.

What Is the Classic Presentation for Ogilvie’s Syndrome?

This occurs in critically ill patients or those recovering from non-abdominal surgery (such as orthopedic, cardiothoracic). The etiology is likely multifactorial but involves a functional pseudo-obstruction of the large bowel (not small bowel). In stable patients, it can initially be managed with supportive care (correction of fluids/electrolytes, nasogastric decompression,

and discontinuation of narcotic {antimotility} medications) and elimination/correction of predisposing conditions. If this fails, then pharmacologic treatment with neostigmine is indicated. Patients must be on cardiac monitoring to receive neostigmine. Do not give in pregnant patients or when uncontrolled cardiac arrhythmias or severe active bronchospasms is present. If this fails, colonoscopic decompression (suctioning out the excessive air) can be helpful.

Watch Out

Neostigmine is contraindicated in patients with heart block due as they can develop significant bradycardia. Atropine should always be available in the room when patients are receiving neostigmine.

What Are the Five Fs of Abdominal Distention?

These are the five common causes of abdominal distention: fat (obesity), feces (fecal impaction), fetus (pregnancy), flatus (ileus or obstruction), and fluid (ascites). Flatus and fluid can be distinguished by whether the abdomen is tympanitic (gas) or dull (fluid) to percussion.

Etiology/Pathophysiology

What Are the Most Common Causes of LBO?

In the USA, malignancies (primarily colon cancer) are the most common cause of LBO (more than half of cases), followed by diverticulitis (either acute or chronic with a stricture) and then volvulus.

Watch Out

Remember that volvulus is considered a closed-loop obstruction which if left untreated will progress to intestinal ischemia, necrosis, and perforation.

Where in the Colon Is a Cancer Most Likely to Cause an LBO?

Left-sided colon (smaller diameter) cancers are more likely to cause LBO, whereas right-sided colon cancers are more likely to present with iron deficiency anemia.

What Is the Difference Between Malrotation and Volvulus?

Malrotation is a congenital condition in which the bowel does not reside in its normal anatomic position. As a result,

the bowel and its mesentery are not properly fixed/attached and are therefore prone to twisting and becoming obstructed. Provided the bowel and its mesentery do not twist, the malrotation remains asymptomatic. Volvulus is the term used to describe the twisting of the bowel and is an example of a *closed-loop obstruction*. Volvulus can be a manifestation of malrotation. If the small bowel twists, the term used is mid-gut volvulus. Volvulus can also occur in the absence of malrotation (i.e., sigmoid volvulus).

Watch Out

In some cases of a closed-loop obstruction such as with volvulus, the venous outflow may be completely obstructed which will prevent the high level of lactate released from ischemic/necrosed bowel from reaching systemic circulation, and so the serum lactate level will be falsely low.

How Does the Etiology Differ Between Sigmoid and Cecal Volvulus?

Cecal volvulus is thought to be due to a congenital partial malrotation, in which the cecum and right colon are not fixed. As such it presents in younger patients. Sigmoid volvulus is an acquired condition, thought to be caused by progressive stretching and redundancy of the sigmoid colon, which then twists on its narrow mesentery.

What Are the Risk Factors for Sigmoid Volvulus?

Factors that lead to stretching and redundancy of the sigmoid include anticholinergic drugs (which impair motility), neurologic and psychiatric diseases (likely due to chronic constipation with stool retention), cystic fibrosis, Chagas' disease, and high-fiber diet. Such a diet tends to create large, bulky stools that stretch out the sigmoid colon. Sigmoid volvulus is seen more commonly in regions that are part of the so-called volvulus belt which includes Brazil, sub-Saharan Africa, and the Middle East, where diets are high in vegetables and fruits.

Watch Out

Low-fiber diet increases risk for diverticula, while a high-fiber diet increases risk for sigmoid volvulus.

What Is Meant by the Term Complicated Volvulus?

Complicated volvulus implies that there is bowel ischemia and its sequelae, such as gangrenous bowel and sepsis. This can be recognized on history and physical by the following: severe diffuse abdominal pain, fever, tachycardia,

altered mental status, marked tenderness to palpation with peritoneal signs, and laboratory evidence of bowel ischemia such as a leukocytosis, hyponatremia, and metabolic acidosis. The distinction between uncomplicated and complicated volvulus is important as it has therapeutic implications.

Watch Out

A low bicarbonate level suggests lactic acidosis and bowel ischemia.

Workup

What Are the First Steps in the Workup of a Suspected Large Bowel Obstruction?

The first steps are to obtain laboratory values and to include complete blood count, serum lactate (alternatively, bicarbonate), and serum chemistries to determine electrolyte abnormalities and the presence of volume depletion. Leukocytosis (with a left shift), hyponatremia, and lactic acidosis are concerning for the presence of bowel obstruction with ischemia, or complicated volvulus. In addition, the physical exam should evaluate for peritoneal signs, such as rebound or rigidity, indicative of an acute abdomen.

Watch Out

Hyponatremia is a less well-recognized but emerging laboratory abnormality associated with severe infection, bowel perforation, and ischemic tissue.

What Is the First Imaging Recommended for a Suspected Large Bowel Obstruction?

Plain abdominal (supine and upright) and upright chest radiographs (to look for free air under the diaphragm) should be obtained. Plain abdominal x-rays can generally distinguish between an SBO (dilated loops of small bowel with multiple air fluid levels) and an LBO.

How Is Cecal Volvulus Differentiated from Sigmoid Volvulus on X-Ray?


Because cecal volvulus involves the proximal colon, these patients are more likely to have radiographic evidence of small bowel obstruction, compared to sigmoid volvulus. They also will have distended large bowel with the apex pointing toward the *left upper quadrant*. Sigmoid volvulus will have the apex pointing toward the *right upper quadrant*.  Figure 25.1 demonstrates the classic x-ray finding of a “coffee bean” sign for sigmoid volvulus.



Fig. 25.1 Abdominal x-ray showing the “coffee bean” or “bent inner tube” sign of sigmoid volvulus

What Additional Imaging Is Recommended?

If the plain films are diagnostic of a volvulus, no further imaging is necessary. CT with oral and IV contrast is recommended if the diagnosis of large bowel obstruction is unclear. For volvulus it often demonstrates a “whirl” sign indicative of mesenteric twisting and dilated colon. CT has nearly 95% sensitivity for detecting volvulus. CT may also be useful in assessing for other potential diagnoses, such as neoplasm, diverticular disease, and hernias. An alternative imaging modality is the contrast enema (provided there is no concern for perforation), which demonstrates a “bird’s beak” or “ace of spades” sign of narrowing at the point of obstruction. A water-soluble contrast enema may also be therapeutic, in that it can sometimes untwist the volvulus.

Management

What Are the Initial Steps in the Management of a Large Bowel Obstruction at Any Anatomic Location?

Most patients with a LBO require IV fluid resuscitation with placement of a Foley catheter to monitor urine output. A nasogastric tube may be placed for symptomatic relief in the vomiting patient.

Watch Out

Volvulus is a closed-loop obstruction. As such, NG tube decompression alone is not therapeutic.

What Is the Subsequent Treatment for a Sigmoid Volvulus?

In uncomplicated sigmoid volvulus, the initial treatment of choice is to attempt an untwisting (detorsion) of the volvulus via endoscopy. Flexible sigmoidoscopy, rigid proctoscopy, and colonoscopy are all reasonable therapeutic options; the endoscope is advanced to the point of obstruction and then gradually advanced through the closed loop, decompressing it with an ensuing rush of gas and fecal contents. Care is then taken to inspect the mucosa for any signs of ischemia before removing the endoscope. In general, a rectal tube should be placed for prevention of retorsion and continued decompression. Contrast enema is another therapeutic option in reducing the volvulus but does not offer the benefit of allowing mucosal inspection. If detorsion fails, the patient must undergo urgent surgery.

Following Successful Detorsion of Uncomplicated Sigmoid Volvulus, What Is the Next Step in the Management?

The recurrence rate after endoscopic detorsion of sigmoid volvulus is quite high. Thus, in most cases, the patient will be scheduled for semi-elective sigmoid resection with or without primary anastomosis. The advantage of first performing endoscopic detorsion is that it addresses the acute problem, allowing for surgery to be performed less urgently, after fluid resuscitation and optimization of surgical risk factors. It also may prevent the need for a colostomy, as the ends of the colon can be anastomosed primarily. Some evidence suggests that elderly patients with significant comorbidities who are poor candidates for surgery may be managed nonoperatively.

How Is Complicated Sigmoid Volvulus Managed?

Complicated sigmoid volvulus implies clinical suspicion for colonic ischemia and/or perforation, and as such, the colon needs to be resected. Thus, endoscopic detorsion and contrast enemas should *not* be attempted. Intraoperatively, if the volvulized bowel is confirmed to be ischemic, it should not be detorsed but instead resected to prevent entry of bacteria and toxins into the systemic circulation. The colon is resected to viable margins. The proximal end of the colon is brought out as a colostomy.

What Is the Treatment for a Cecal Volvulus?

Cecal volvulus is associated with a higher rate of bowel necrosis, failure of endoscopic detorsion, and recurrence. Thus, attempted endoscopic detorsion is not recommended, and surgery is considered the first-line treatment.

for cecal volvulus (right colectomy with a primary anastomosis).

What Factors Determine Outcomes of Volvulus?

The primary determinant of outcome is whether the volvulus is complicated or uncomplicated. Colonic ischemia and/or gangrene can precipitate septic shock with a high mortality rate.

Area Where You Can Get in Trouble

LBO in Pregnancy

LBO may not be readily recognized in pregnant patients, yet colonic volvulus is the second most common cause of intestinal obstruction in pregnancy (after SBO due to adhesions). Detorsion is indicated, but resection may be delayed until after delivery to improve surgical risk for the fetus and mother, especially given that most cases occur in the third trimester and thus may not result in a significant delay.

Area of Controversy

Percutaneous Endoscopic Colostomy Tubes

A less invasive and newly emerging treatment is the placement of two percutaneous endoscopic colostomy (PEC) tubes, similar in concept to the percutaneous endoscopic gastrostomy (PEG). Placing two tubes may provide adequate fixation to prevent recurrence until abdominal-colonic adhesions have time to form. However, this is not routinely performed in most centers.

Summary of Essentials

History and Physical

- LBO – gradual and severe abdominal distention, obstipation, and vomiting.
- Uncomplicated volvulus – normal vitals, normal mental status, and non-tender abdomen.
- Complicated volvulus – severe abdominal pain, fever, tachycardia, toxic appearance, peritoneal signs, acidosis, and leukocytosis.
- Look for abdominal scars and hernias and perform a rectal exam to assess other differential diagnoses.

Etiology/Risk Factors

- Most common causes of LBO
 - Cancer
 - Diverticulitis
 - Volvulus
- Sigmoid volvulus – acquired stretching of the sigmoid
 - Neuropsychiatric disease, institutionalization, chronic constipation, long-term anticholinergic use, high-fiber diet, and pregnancy
- Cecal volvulus – congenital failure of fixation of the cecum

Diagnosis

- Compared to LBO, SBO has faster onset and more likely to cause vomiting and high-pitched bowel sounds.
- Patients with Ogilvie's syndrome are more likely to be already hospitalized and bedridden, often in the postoperative setting.
- Abdominal x-ray:
 - Sigmoid volvulus – “coffee bean sign” in right upper quadrant, “omega,” or “bent inner tube,” “kidney bean” sign
 - Cecal volvulus – “comma” or “kidney bean” sign, “coffee bean” sign in left upper quadrant
- CT scan if equivocal x-ray findings.
- Contrast enema may be diagnostic (“bird's beak” sign) and therapeutic in reducing the volvulus:
 - Water-soluble contrast (Gastrografin) rather than barium, to avoid peritonitis and scarring in case of perforation and barium leak.
 - Bowel wall thickening, mesenteric edema, pneumatosis, and portal venous gas suggest ischemic bowel.

Management

- Therapy differs based on the location and severity of complication
 - Uncomplicated sigmoid volvulus – endoscopic detorsion with rectal tube placement followed by semi-elective resection
 - Complicated sigmoid volvulus – no detorsion attempted; emergent laparotomy with resection
 - Cecal volvulus – no detorsion attempted; take to OR for right colectomy
- Complications of surgery – wound infection, anastomotic leak, and recurrence. Without detorsion or resection – ischemia, perforation, and sepsis

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Left Lower Quadrant Pain and Fever

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Case Study

A 55-year-old obese female presents with a 2-day history of left lower quadrant (LLQ) pain, nausea, anorexia, and low-grade fevers. The patient states that the pain is constant and moderately severe and does not radiate anywhere. She does not recall anything that precipitated the pain. She has not eaten in 24 hours as she is not hungry. She has had no bowel movement for 48 hours. She denies vomiting or bloody or black stools and has no recent change in bowel habits, though she says she's been constipated

most of her life. She has noted similar pain in the past, but never this severe, and has never sought medical attention before. She has never had a screening colonoscopy. Past history is significant for hypertension and diabetes. She has no prior surgery. On physical examination, blood pressure is 130/70 mmHg, heart rate 110/min, temperature is 38.2 °C, and respiratory rate is 16/min. Abdominal exam reveals mild distention, no surgical scars, and no masses. Bowel sounds are absent. The LLQ is

moderately tender to palpation with guarding and no rebound tenderness. The remainder of the abdomen is nontender. Rectal exam is unremarkable. Pelvic exam reveals no cervical motion tenderness and no adnexal masses. Laboratory exam demonstrates a white blood cell (WBC) count of $16 \times 10^3/\mu\text{L}$ (normal $4.1\text{--}10.9 \times 10^3/\mu\text{L}$) with a left shift, hemoglobin of 13 g/dL (12–15 g/dL) and hematocrit of 39% (35–46%), normal electrolytes, and normal urinalysis.

Diagnosis

What Is the Differential Diagnosis?

Table 26.1

Condition	Comments
<i>Acute diverticulitis</i>	Inflammation of diverticula; most commonly in the sigmoid colon; LLQ pain; usually febrile
<i>Pelvic inflammatory disease</i>	Cervical motion/adnexal tenderness, foul-smelling vaginal discharge, sexually transmitted, most are premenopausal
<i>Acute appendicitis</i>	RLQ pain, fever, anorexia
<i>Sigmoid volvulus</i>	Twisting of the sigmoid colon around its mesentery; more common in elderly patients; presents as large bowel obstruction
<i>Ischemic colitis</i>	Hypoperfusion causes mucosal ischemia, most often to the splenic flexure of colon, usually self-limited, bloody diarrhea
<i>Acute mesenteric ischemia</i>	Sudden onset of severe diffuse abdominal pain out of proportion to examination, acute occlusion of SMA, ischemia to the entire small bowel
<i>Inflammatory bowel disease</i>	History of abdominal cramps, bloody diarrhea, acute abdominal pain
<i>Colon cancer</i>	Change in bowel habits, weight loss, blood in stool

LLQ left lower quadrant, RLQ right lower quadrant, SMA superior mesenteric artery

What Is the Most Likely Diagnosis?

Given the patient's age, LLQ pain and tenderness on exam, associated fever, and leukocytosis, acute diverticulitis is the most likely diagnosis.

History and Physical

What Are the Risk Factors for Diverticulosis?

Obesity, low-fiber and high-fat diet, red meat, constipation, opiate abuse, and advanced age.

Pathophysiology

Where in the Colon Do Diverticula Occur Most Frequently? Which Diverticula Are More Prone to Infection? Bleeding?

The vast majority of diverticula occur in the sigmoid colon. Diverticula in the left or sigmoid colon are more likely to become infected (diverticulitis). Diverticula in the right colon are more likely to bleed (diverticulosis).

Do Diverticula Occur in the Rectum? Why/Why Not?

Rectal diverticula are extremely rare. It is hypothesized that they almost never occur because the taenia coli, the longitudinal bands of smooth muscle along the colon, coalesce into a circumferential band around the rectum, thereby eliminating points of weakness that predispose to diverticula.

What Are True and False Diverticula? Which Type Are Sigmoid Diverticula?

There are four layers of the intestinal wall: the mucosa, submucosa, muscularis propria, and serosa. In a true diverticulum (congenital), all layers are part of an outpouching of the

intestine. In a false diverticulum (acquired), only the mucosa and submucosa are part of the outpouching. The most common diverticula are acquired (such as sigmoid diverticulitis).

What Are the Main Complications of Diverticulitis? How Would They Present?

Table 26.2

Complication	Presentation
<i>Abscess</i>	Fever, localized pain, ileus, leukocytosis
<i>Perforation</i>	May seal spontaneously via the omentum (microperforation); can progress to purulent or feculent peritonitis (free perforation); diffuse abdominal tenderness, ileus, leukocytosis, fever
<i>Fistula</i>	Colovesical (refractory multi-organism urinary tract infection, pneumaturia, fecaluria); colovaginal (feculent vaginal discharge)
<i>Stricture</i>	Partial large bowel obstruction; abdominal distention, constipation, bloating
<i>Large bowel obstruction</i>	Feculent vomiting, abdominal distention, obstipation, crampy abdominal pain

What Are the Main Etiologies for a Colovesical Fistula? Colovaginal Fistula?

The most common cause for a colovesical fistula is diverticulitis. Other causes are colon cancer, IBD, bladder cancer, radiation injury, trauma, or foreign body. Although diverticulitis can also lead to a colovaginal fistula, nearly 80% of all colovaginal fistulas are due to obstetric injury.

How Does a Colovesical Fistula Present?

Patients with colovesical fistula may present with fecaluria (feces in the urine), pneumaturia (air in the urine), recurrent urinary tract infections that are refractory to treatment, or as a urinary tract infection caused by multiple enteric organisms or anaerobes (most routine urinary tract infections are single organism and aerobes).

What Is Meant by Complicated Versus Uncomplicated Diverticulitis? What Is the Implication?

Diverticulitis that occurs with abscess formation, colonic obstruction, diffuse peritonitis, or fistulization is considered

complicated diverticulitis, whereas diverticulitis without these sequelae is known as uncomplicated diverticulitis.

What Is the Hinchey Staging System?

This is a grading schema to describe the severity of complicated diverticulitis: stage I, pericolic inflammation with pericolic abscess; stage II, retroperitoneal or pelvic abscess; stage III, purulent peritonitis; and stage IV, fecal peritonitis. Most surgeons consider stages II–IV as complicated diverticulitis.

Workup

What Imaging Is Recommended?

CT scan (■ Figs. 26.1 and 26.2) is recommended in patients suspected of having diverticulitis.

What Two Diagnostic Studies Are Contraindicated in the Acute Setting of Suspected Diverticulitis and Why?

Barium enema introduces fluid under pressure, which may unseal a contained perforation. Barium would then leak into the peritoneum, causing barium peritonitis (CT scans with oral contrast are safe as they use water soluble contrast). Colonoscopy may similarly worsen diverticulitis as it increases pressure due to air insufflation. However, it is imperative that colonoscopy be performed 6–8 weeks after recovering from the acute episode, in order to rule out unexpected causes of the colonic inflammation such as IBD or malignancy.



■ Fig. 26.1 Axial CT of the pelvis showing a normal sigmoid colon with thin walls and filled with stool. There are no diverticula

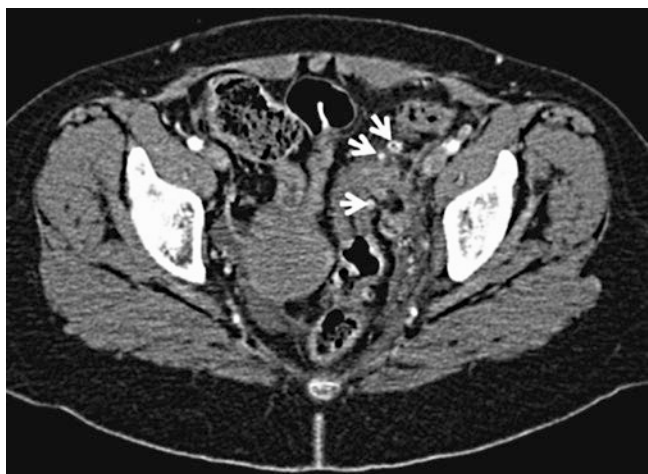


Fig. 26.2 Axial CT of the pelvis demonstrating sigmoid diverticula with significant wall thickening of the sigmoid colon, consistent with acute sigmoid diverticulitis. *White arrows: diverticula*

Management

What Is the First Step in the Management of Suspected Acute Diverticulitis?

Determine if the patient has complicated or uncomplicated diverticulitis and whether the patient demonstrates evidence of systemic infection such as fever, tachycardia, and leukocytosis. If the episode of diverticulitis is uncomplicated and without evidence of a systemic response, the patient can be discharged home with oral antibiotics and clear liquids. Patients with acute diverticulitis who have significant pain or have a systemic response should be admitted to the hospital, placed NPO, and given IV antibiotics, fluids, and analgesia.

What Is the Subsequent Management for Uncomplicated Diverticulitis?

The majority will resolve with the approach described above, without the need for surgery, and will not have another episode. The patient should be counseled on dietary modification (decrease fats and increase fibers). If the patient fails to improve while hospitalized (persistent abdominal pain and tenderness, worsening leukocytosis), the options are to broaden the antibiotics, to repeat the CT scan to look for an abscess that might require drainage, or to take the patient to the operating room for a colon resection.

What Operation Is Performed in the Elective Setting for Sigmoid Diverticulitis? How Is This Operation Different than Surgery in the Urgent or Emergent Setting?

In the setting of recurrent uncomplicated diverticulitis, preventive surgery may be performed, and patients may undergo

a one-step procedure wherein the diseased colon is resected and the proximal and distal segments are connected to one another. This is known as primary anastomosis. In the emergent or urgent setting, resection of the diseased colon without an anastomosis (resulting in a temporary end colostomy) is often performed. At a later time, the proximal and distal ends of the remaining colon can be anastomosed.

Complicated Diverticulitis

What Is the Management of Complicated Diverticulitis?

Depending on the specific complication, the recommendation is either urgent surgery, CT-guided drainage, or delayed surgery.

What Are the Indications for Urgent Surgery? What Operation Is Recommended in the Urgent Setting?

Patients with evidence of diffuse peritonitis as a result of free colonic perforation should undergo urgent surgery. In this setting, the diseased colon is removed, and an end colostomy is performed with the distal rectum closed and left in the abdomen (known as a Hartmann procedure). After the inflammation of acute diverticulitis resolves, the end colostomy may be reversed and reattached to the rectum (usually 6 months later).

How Does One Determine the Proximal and Distal Extent of Colon Resection? What if There Are Diverticula Throughout the Colon?

The proximal margin of resection should be proximal to the diseased colon (as evidenced by soft and non-inflamed bowel), but it is *not necessary* to resect all diverticula-containing colon if it is not inflamed. The distal segment of resection should be to the start of the rectum, identified by the absence of distinct taenia coli.

What Is the Recommended Treatment for Diverticulitis Complicated by a Localized Abscess?

Patients with a pericolic abscess with diameter less than 4 cm and without peritoneal signs can be treated with bowel rest and broad-spectrum antibiotics. If the abscess is larger than 4 cm, and they only have localized tenderness, antibiotics plus CT-guided percutaneous drainage is indicated, as this will facilitate resolution of acute inflammation, which may allow for a one-stage surgical resection of the affected bowel at a later date. Remember, there is an abscess (Hinchey stage II and greater), so this is complicated diverticulitis.

What Is the Recommended Treatment for Diverticulitis with a Colovesical Fistula?

The affected segment of the colon should be resected electively. For the bladder, simple drainage by a Foley for a brief time is recommended. In poor surgical candidates, medical management with antibiotic therapy may be considered.

Table 26.3 Management of complicated diverticulitis

Complication	Management
Free perforation without peritonitis	CT-guided drainage followed by elective colon resection
Free perforation with diffuse peritonitis	Emergent colectomy with end colostomy
Large bowel obstruction	Urgent colectomy with possible end colostomy
Large (>4 cm) localized abscess	CT-guided drainage followed by elective colon resection
Small (<4 cm) localized abscess	IV antibiotics
Colovesical fistula	Elective colon resection and bladder drainage with Foley

Is the Presence of Free Air on CT an Absolute Indication for Urgent Surgery?

Not necessarily. It has been shown that patients with acute diverticulitis with free intraperitoneal air, thereby meeting criteria for complicated diverticulitis, can be treated effectively with supportive care and possible percutaneous abscess drainage (Table 26.3) provided they do not have diffuse peritonitis. These patients may undergo sigmoid colectomy at a later date.

Areas Where You Can Get in Trouble

Not Identifying the Ureter During Sigmoid Colon Resection

The ureters are retroperitoneal structures and are at risk of damage or complete transection during colonic resection if not identified.

Elderly Patient with Chronic Constipation and NSAID Use, with Sudden Abdominal Pain

This is concerning for a stercoral ulceration complicated by perforation. It is a rare condition that typically affects elderly patients that suffer from chronic constipation. The hard stool travels through the rectosigmoid colon and develops into a fecaloma which can result in local ischemia, ulceration, and subsequent perforation leading to a sudden onset of abdominal pain. Sometimes the only clue that a patient may be suffering from chronic constipation is the use of laxatives. The use of NSAIDs has been found to be a risk factor for stercoral ulceration.

Areas of Controversy

How Many Episodes of Uncomplicated Diverticulitis Are Acceptable Before Elective Surgery Is Recommended?

Most studies show that the rate of recurrence after diverticulitis is 10–30%. There is currently no strict number of episodes of diverticulitis before surgery is recommended. Therefore, even patients with repeated episodes of uncomplicated diverticulitis may be managed medically as long as treatment remains effective. The decision is individually based and depends on medical comorbidities and the patient's preference.

Benefit of Bowel Prep Before Elective Colon Surgery

It has long been believed that mechanical bowel prep (one or more laxatives) will reduce colonic bacterial burden and thus reduce the risk of infection. Recent literature now supports mechanical bowel prep and oral antibiotic bowel preparation along with systemic preoperative antibiotics.

Summary of Essentials

History and Physical

- Major risk factors are obesity, advanced age, and diet low in fiber, high in fat, high in red meat, and opiate abuse.
- Diverticulitis is a clinical diagnosis (LLQ pain and tenderness, fever, leukocytosis).

Pathophysiology

- The sigmoid colon is the most common site.
- Complicated diverticulitis: abscess, free perforation, fistula, stricture, and obstruction.

Diagnosis

- CT scan is the first-line imaging modality.
- Avoid barium enema and colonoscopy in acute presentation because of increased risk of perforation.
- Determine if complicated or uncomplicated.
- Presence or absence of systemic markers (fever, tachycardia, leukocytosis).

Management

- Uncomplicated diverticulitis without systemic markers
 - Treated as outpatient
 - Oral antibiotics and clear liquids
- Uncomplicated diverticulitis with systemic markers
 - Admit to hospital.
 - NPO, IV fluids, IV antibiotics, and analgesia.
 - Follow up with colonoscopy 6–8 weeks after acute episode to rule out malignancy.
- Complicated diverticulitis with large abscess
 - CT-guided drainage
- Complicated diverticulitis with free air and diffuse peritonitis
 - Resect the affected colon with temporary end colostomy.

Suggested Reading

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Fatigue and Bloody Diarrhea

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Case Study

A 19-year-old female presents with fatigue for the past 3 months. She is of Ashkenazi Jewish origin. She reports a 2-year history of diarrhea accompanied by abdominal pain and cramping. Her stool is sometimes tinged with blood as well as mucus. She also has intermittent aches and malaise. Her stature is short relative to her parents. She smokes ½ a pack of cigarettes per day. On physical examination, the patient appears pale and thin. She has several small painful sores inside her mouth. Her abdominal exam is unremarkable. Her legs demonstrate several red nodules that are tender to palpation. Anal exam reveals perianal skin tags. Her laboratory studies demonstrate a hemoglobin of 7.5 g/dL (normal 12–15.5 g/dL).

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Diagnosis

What Is the Differential Diagnosis of Chronic Diarrhea with Mucus and/or Blood?

Table 27.1

Diagnosis	Comments
<i>Irritable bowel syndrome (IBS)</i>	Chronically altered bowel habits (constipation and/or diarrhea, and stool form), bloating; crampy abdominal pain, mucus in stool, <i>without</i> blood
<i>Infectious colitis (Shigella, Salmonellae, Campylobacter, Yersinia)</i>	Fever, watery diarrhea, nausea, vomiting, abdominal cramping; acute onset; <i>Shigella</i> and <i>Yersinia</i> colitis may present with bloody stools and mucus
<i>Inflammatory bowel disease</i>	Abdominal pain, fatigue, anemia, weight loss, intermittent diarrhea, enterocutaneous and perianal fistulae/disease, erythema nodosa
<i>Celiac disease</i>	Flatulence, weight loss, malabsorption, steatorrhea
<i>Diverticulitis</i>	Left lower quadrant pain, constipation, diarrhea (less common)
<i>Pseudomembranous colitis</i>	<i>Clostridium difficile</i> infection; abdominal pain/cramping, diarrhea; recent antibiotic use (e.g., clindamycin); yellow plaques found on colonoscopy

What Are the Key Differences Between Ulcerative Colitis and Crohn's?

Table 27.2

	Crohn's	Ulcerative colitis
Location	Anywhere from the mouth to anus, " Gum to bum ," terminal ileum is the most common site	Starts in the rectum and may extend proximally to colon
Distribution	Can be discontinuous (skip lesions)	Continuous
Symptoms	Varies but can be abdominal pain, weight loss, bloating, diarrhea, mucus in bowel movements	Abdominal pain with bloody diarrhea and mucus
Gross appearance	Cobblestone mucosa, creeping fat, fistulas, strictures	Pseudopolyps, barium enema may show " lead pipe " colon devoid of haustra
Depth of inflammation	Transmural (entire bowel wall affected)	Shallow, mucosal
Histology	Lymphoid aggregates with noncaseating granulomas in only 15% of endoscopic biopsy	Crypt abscesses with neutrophils
Complications	Malabsorption and nutritional deficiency, oral ulcers, fistula formation , calcium oxalate nephrolithiasis, gallstones, colorectal cancer	Primary sclerosing cholangitis, toxic megacolon, colorectal cancer with increasing risk after 10 years with the disease
Cancer risk	Increased 8–10 years after diagnosis	Increase 8–10 years after diagnosis
Labs	ASCA frequently positive, pANCA rarely positive	ASCA rarely positive, pANCA frequently positive
Granulomas	Yes	No

Watch Out

Use “Green *CHRISTMAS*” to help remember the key features of Crohn’s: *granuloma, cobblestones, hyperthermia, reduced lumen, intestinal fistula, skip lesions, transmural, malabsorption, abdominal pain, submucosal fibrosis.*

What Is the Diagnosis for This Patient?

In a young patient presenting with short stature, insidious history of diarrhea with blood or mucus, perianal disease (skin tags), and extracolonic manifestations such as joint ache, aphthous ulcer, and erythema nodosa, the most likely diagnosis is Crohn’s. Additionally, inflammatory bowel disease (IBD) is more common in patients of Ashkenazi Jewish origin.

History and Physical**What Is the Age Distribution of Inflammatory Bowel Disease (IBD)?**

IBD typically demonstrates a bimodal distribution with initial (and greater) incidence of the disease occurring between ages 20 and 30. In this younger age group, Crohn’s occurs more commonly than ulcerative colitis. The second (and lower) peak in incidence of IBD occurs between ages 60 and 80 with a greater propensity for ulcerative colitis over Crohn’s. While the exact etiology of this bimodal distribution remains unknown, potential hypotheses include changes in the immune system during aging as well as increased exposure to environmental stimulants.

What Are the Risk Factors for IBD?

Risk factors for IBD are multifactorial: genetic components, environmental exposures, and host microbiome. Particular ethnic groups predisposed to higher rates of IBD include certain Jewish populations. The hygiene hypothesis has been postulated as a risk factor as well. Children raised in urban settings with presumably more hygienic upbringings have higher rates of IBD. A reduction in enteric antigen exposure during childhood may lead to altered immunological function. Crohn’s has been demonstrated to occur at higher rates in families with fewer siblings. Reduction in the biodiversity of the gut flora has been associated with higher incidence of IBD.

Is Smoking a Risk Factor for Both Crohn’s and UC?

Smoking appears to be a risk factor for Crohn’s with higher rates in patients who are active smokers as well as ex-smokers. In comparison, patients that are active smokers tend to dem-

onstrate a reduction in incidence of ulcerative colitis. Smoking may also improve symptoms in patients with ulcerative colitis. Nicotine appears to induce a complex effect on mucosal epithelial cells as well as T-cell function resulting in modulation of cytokine levels and immune function.

How Do Patients with IBD Typically Present Clinically?

The classic presentation differs between ulcerative colitis and Crohn’s. Since ulcerative colitis begins in the rectum, it typically presents with crampy abdominal pain and bloody diarrhea. Since Crohn’s can affect any part of the GI tract, the presentation is much more variable. Classically it presents with intermittent or insidious onset of abdominal pain, weight loss/growth failure, and diarrhea. Bloody diarrhea is less common with Crohn’s. Secondary effects include volume depletion, anemia, electrolyte disturbances, and hypoalbuminemia. Due to the effect of Crohn’s on the small bowel, nutritional deficiencies and malabsorption are more common in comparison to ulcerative colitis. Acute episodes of Crohn’s can be associated with intra-abdominal abscesses. Crohn’s can lead to intestinal strictures (leading to bowel obstructive symptoms) and fistulas to the skin. Additionally, Crohn’s is more commonly associated with perianal disease including skin tags, perianal abscesses, and anal fistulas; ulcerative colitis does not typically present with perianal disease.

What Are the Extraintestinal Manifestations of IBD?

Musculoskeletal manifestations are most common (peripheral and axial arthropathy). Cutaneous disorders include erythema nodosa or pyoderma gangrenosum. Oral manifestations include aphthous ulcers and mucosal/gingival lesions. Ophthalmologic manifestations include uveitis and episcleritis. Primary sclerosing cholangitis (PSC), an inflammatory fibrotic process affecting the intrahepatic and extrahepatic biliary ducts, has strongly been associated with inflammatory bowel disease, more commonly with ulcerative colitis. The clinical presentation of PSC includes progressive jaundice and pruritis, with periodic acute episodes of hepatitis and jaundice. Progressive dysfunction associated with PSC culminates in cirrhosis, ascites, and hepatic encephalopathy. PSC is the strongest risk factor for the development of cholangiocarcinoma. Gallstones are more common with Crohn’s (terminal ileitis).

What Is the Significance of Growth Retardation and Delayed Onset of Puberty?

IBD has been associated with impaired oral intake, vitamin and mineral deficiencies, and abnormal intestinal absorption all of which contribute to a detrimental effect on growth and

puberty. The pro-inflammatory state and increased levels of cytokines such as TNF- α can lead to increased anorexia. This has been shown to affect up to 80% of children diagnosed with Crohn's. Subsequent effects include growth retardation and delay in the onset of puberty as well as impaired linear growth and delayed onset of menarche.

What Is Tenesmus?

Tenesmus is the sense of incomplete defecation (even if bowel contents are empty). It is characterized by a continual or recurrent inclination to evacuate the bowels. It may be associated with rectal pain, abdominal cramps, and fecal urgency. It is associated with irritable bowel syndrome as well as with conditions that cause inflammation of the colonic or rectal mucosa.

Pathophysiology

What Is the Final Common Pathway for the Pathogenesis of IBD?

Inflammation: this is important because most therapeutic interventions directly or indirectly downregulate the immune system.

Are Patients with IBD at Increased Risk for Cancer?

Yes, chronic intestinal inflammation is a primary risk for developing cancer. These include colorectal cancer, cholangiocarcinoma (mostly associated with sclerosing cholangitis and ulcerative colitis), small bowel adenocarcinoma (more with Crohn's and more in the ileum), and intestinal lymphoma (more with Crohn's). The risk of cancer is related to the duration of illness and the extent of disease. Sporadic colon cancers develop from a dysplastic polyp and are therefore initially localized. With IBD, however, the dysplasia can be multifocal and diffuse. For ulcerative colitis, the risk is low in the first 10 years of the disease (2–3%) but grows to 1–2% per year afterwards.

What Is the Screening Recommendation for Colon Cancer in IBD?

Current screening guidelines recommend the first screening colonoscopy 8 years after initial diagnosis of UC. The same guideline is recommended for patients with Crohn's who have colonic involvement. Colonoscopy is recommended immediately in patients with newly diagnosed PSC (much higher risk of colon cancer). Because cancer can develop in the absence of polyps, random biopsies are recommended. Subsequent endoscopic surveillance is determined based on risk stratification. In high-risk patients including those with

extensive, severe inflammation, long-standing IBD diagnosis, or previously identified low-grade dysplasia, annual endoscopic surveillance is recommended. In patients with intermediate risk (mild to moderate inflammation, inflammatory polyps), surveillance is recommended every 3 years, while in patients with low risk, surveillance can be extended to 5 years. If high-grade dysplasia (or malignancy) is found on a random biopsy, a restorative proctocolectomy with ileoanal pouch anastomosis is recommended.

What Portion of the GI Tract Is Most Commonly Affected in Crohn's?

Crohn's can affect any part of the gastrointestinal tract, but involvement of the ileum is most common and occurs in up to 2/3 of patients.

What Complications Affect IBD Patients?

In patients with Crohn's, since the inflammation is full thickness, they have a tendency to form fistulas to other organs. These include enterovesical (small bowel to bladder) and colovesical (colon to bladder) fistulas (which can present as recurrent multi-organism urinary tract infections). Crohn's commonly features perianal disease including skin tags, perirectal abscesses, and anal fissures. The transmural inflammation associated with Crohn's can also lead to stricture formation. Strictures and intra-abdominal adhesions can both contribute to intestinal obstruction as well. Malabsorption as well as reduced reabsorption of bile into the enterohepatic circulation can lead to protein and both water-soluble and fat-soluble vitamin deficiencies as well as gallstones. With ulcerative colitis, patients may develop intractable bloody diarrhea. The severe mucosal inflammation, with attendant interruption of the protective mucosal barriers, may lead to secondary bacterial infection and a life-threatening toxic megacolon.

What Types of Anemia Are Seen with IBD?

Both ulcerative colitis and Crohn's patients frequently have iron deficiency anemia. This is related to chronic loss of blood in the GI tract, effects of chronic inflammation, as well as decreased duodenal iron absorption (more often in Crohn's). Less commonly, B12 deficiency anemia may occur and occurs more often in Crohn's patients since vitamin B12 is absorbed in the terminal ileum. These patients may present with the pernicious anemia triad:

1. Megaloblastic anemia due to inhibition of DNA synthesis
2. GI symptoms: bowel motility changes
3. Neurological symptoms: absent reflexes, diminished vibration or soft touch sensation, subacute combined degeneration of spinal cord, seizures, and dementia

Table 27.3 Nutritional deficiencies in IBD

Risk factor	Comment
Vitamin B9 (folate)	Present in 30% of Crohn's patients and 10% of ulcerative colitis. This can contribute to megaloblastic anemia
Vitamin B12	Ileal inflammation or prior resection of the terminal ileum can reduce intrinsic factor absorption
Vitamin A	Low serum retinol levels detected in up to 30% of Crohn's disease patients
Vitamin D	Is associated with low serum calcium levels in IBD patients
Vitamin E	Acts as a free scavenger radical, supplementation may sometimes be necessary for IBD patients
Vitamin K	Plays a role in coagulation factor production as well as development of bone mineral density

What Other Nutritional Deficiencies May IBD Patients Have?

Approximately 20–85% of IBD patients have varying degrees of nutritional deficiencies (Table 27.3). Protein malnutrition has been characterized as the most common feature.

What Conditions Will Prevent Fistulas from Closing?

Conditions that prevent fistulas from spontaneously closing can be remembered by the acronym “HIS FRIEND”: high fistula output (>500 cm³/day), inflammatory bowel disease, short fistula (<2.5 cm), foreign body, radiation, infection, epithelialization, neoplasm, and distal obstruction.

Workup

What Laboratory Studies Are Recommended? What Serology Is Recommended?

Patients should have a complete blood count and vitamin B12 level checked. Other studies that may help in evaluating for IBD include ESR, CRP, and albumin. pANCA is more frequently positive in UC, while cANCA positivity is more common in Crohn's.

What Is the Primary Modality for Diagnosing IBD?

Colonoscopy serves as the preferred diagnostic modality and to determine the extent of disease. However, this is not best

done during an acute or initial presentation of IBD as it increases the risk of iatrogenic perforation. Once inflammation has resolved, colonoscopy can be performed after a bowel preparation (e.g., GoLYTELY®). With Crohn's, the colonoscope should include inspection of the terminal ileum (ileoscopy). Since Crohn's does not always involve the colon (or even the ileum), other imaging may be necessary.

What Are the Classic Findings on CT Scan?

CT imaging is the primary imaging modality for evaluating an acute presentation of IBD or its complications. IBD patients will have thickened bowel wall, increased mural enhancement with hyperenhancing mucosa, and fibrofatty proliferation of the mesenteric fat (creeping fat sign).

Watch Out

Creeping fat refers to the encroachment of mesenteric fat toward the antimesenteric border of the bowel. It is classically associated with Crohn's (though it can be seen with ulcerative colitis) and can be seen grossly in the operating room. This is considered a pathognomonic finding.

Management

What Are the Medical Therapies Available?

The treatment should be tailored to the degree of inflammation. Medical therapies include 5-ASA agents (mesalazine, sulfasalazine), corticosteroids, immunosuppressant agents (e.g., azathioprine), and biologics (e.g., infliximab). 5-ASA agents are less useful for Crohn's patients. Most clinicians now practice a “top-down” approach where there is an early initiation of more aggressive medications such as biologics which is eventually tailored to more benign medications such as a steroid taper.

Watch Out

5-ASA appears to have a protective effect for colorectal cancer in ulcerative colitis patients.

What Percentage of IBD Patients Will Eventually Require Surgery?

Surgical treatment is required in up to 30% of patients with Crohn's. However, surgery is not curative. Unfortunately, these patients often have recurring symptoms (e.g., obstruction from strictures), and nearly ½ will require additional surgical interventions. The most common reason for surgery in Crohn's is due to obstruction. In contrast, surgery for UC can be curative but usually requires complete removal of the colon and rectum (total proctocolectomy). A pouch or reservoir for stool (much like a new rectum) is created from the ileum (termed a J-pouch) and is anastomosed to the anus.

Though it is possible to leave a rectal cuff, this would create the need for lifelong surveillance for malignant transformation of the remaining rectal mucosa.

Watch Out

The newly created ileal J-pouch can develop recurrent inflammation or infection (termed “pouchitis”). This is treated with metronidazole or ciprofloxacin. However, occasionally the pouchitis represents Crohn’s disease that was incorrectly diagnosed as ulcerative colitis.

What Are the Surgical Indications for Crohn’s? Ulcerative Colitis?

The indications for surgery in Crohn’s and UC vary. Since Crohn’s involves any part of the GI tract, is transmural, and has a tendency to create fistulas and strictures, the more common indications include small bowel obstruction, bowel perforation with acute peritonitis, and bowel perforation with abscess. Since ulcerative colitis is localized to the colonic and to the mucosa, it is more likely to cause bloody diarrhea. Intractable bleeding and toxic megacolon are indications for surgery in ulcerative colitis. For both Crohn’s and ulcerative colitis patients with fulminant disease unresponsive to medical therapy, surgery may also be required. In addition, patients with high-risk dysplasia or colon cancer require surgical resection.

Watch Out

Patients with IBD are at much higher risk of postoperative venous thromboembolic events.

Why Is It Recommended to Avoid Small Bowel Resection with Crohn’s Disease if Possible?

Since the entire GI tract of Crohn’s patients is susceptible to inflammation and thus stricturing, there is a high risk of requiring multiple areas of resection over the lifespan of the patient predisposing to short bowel syndrome. For this reason, it is recommended to only resect small bowel when it is absolutely necessary. Alternative options to bowel resection are to perform a stricturoplasty or bypassing the segment of bowel.

Watch Out

Crohn’s patients undergoing small bowel resection with primary anastomosis have the highest risk of recurrence of inflammation at the anastomosis.

What Are Complications of Removing the Terminal Ileum?

Decrease bile acid pool and vitamin B12 deficiency. As a result of decreased enterohepatic recycling of bile salts, patients also develop deficiency in fat-soluble vitamins (ADEK) and gallstones. Unabsorbed bile acids in the colon also predispose to secretory diarrhea.

In a UC Patient, What Would Be the Concern if They Presented with Sepsis, Diffuse Abdominal Pain, and a Markedly Distended Colon?

This presentation is concerning for toxic megacolon and is a potentially lethal complication of IBD that is characterized by an acute dilation of the colon, typically larger than 6 cm in diameter with a high risk for perforation. The etiology has not been fully elucidated. It is much more common with ulcerative colitis than Crohn’s. These patients are at high risk for septic shock and present with fever, chills, leukocytosis, tachycardia, lactic acidosis, and eventually hypotension and organ failure. In the case of perforation, patients may have free air on x-ray or develop a rigid abdomen with guarding (peritonitis). These patients should be started on IV fluid resuscitation and broad spectrum IV antibiotics and taken to the operating room for total abdominal colectomy.

Areas Where You Can Get in Trouble

Flank Pain and Hematuria in Crohn’s

A Crohn’s patient presenting with flank pain and hematuria should raise suspicion for nephrolithiasis secondary to hyperoxaluria. These patients usually have inflammation at the terminal ileum or a previous resection predisposing them to fat malabsorption. In healthy patients, calcium binds to oxalate to prevent its absorption from the GI tract. In patients with increased amounts of fat in the GI lumen (e.g., ileocolic resection), the calcium preferentially binds to fat leaving the unbound oxalate available for reabsorption and thus increases the risk of developing calcium oxalate renal stones.

Cecal or Terminal Ileum Inflammation in Association with Suspected Appendicitis

Crohn’s can mimic acute appendicitis. If at surgery the appendix appears normal and without inflammation but the terminal ileum and cecum are red and inflamed, the presumptive diagnosis is Crohn’s (in this setting the term regional enteritis is used). These patients may have creeping fat around the ileum. If the cecum is red and inflamed, do not perform an

appendectomy as there is a risk that the stump of the appendix will blow out and form a fistula. These patients should have a postoperative colonoscopy performed. Biopsy of an inflamed cecum should also be avoided as this increases risk for enterocutaneous fistula. If only the terminal ileum is inflamed (and not the cecum), the risk of a fistula is low. It is then reasonable to still proceed with appendectomy so as to avoid future confusion in the advent of future recurrent right lower quadrant pain.

Summary of Essentials

History and Physical

- IBD is multifactorial: genetic components, environmental exposures, and host microbiome.
- Biomodal distribution: age 20–30 and 60–80.
- Smoking is a risk factor for Crohn's but protects against ulcerative colitis.

Pathophysiology

- Crohn's occurs "gum to bum" but most commonly terminal ileum, characterized by skip lesions.
- Ulcerative colitis starts in rectum and only extends to colon continuously.
- Iron deficiency, vitamin B12, and fat-soluble vitamin deficiencies can occur.
- Cancer risk increased 8–10 years after diagnosis and need to be screened.

Diagnosis

- Colonoscopy is the primary modality for diagnosis.
- Creeping fat is a pathognomonic finding for IBD in the operating room, most commonly Crohn's.

Management

- Top down approach with biologics, immunosuppressant agents, 5-ASA agents, steroids.
- Most Crohn's patients ultimately require surgery, most commonly for obstruction.

Suggested Reading

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- Sonnenberg A. Age distribution of IBD hospitalization. *Inflamm Bowel Dis*. 2010;16(3):452–7.
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Question Set: Lower Gastrointestinal

Questions

1. A 4-year-old boy presents to the emergency department with right lower quadrant pain, nausea, and anorexia. On physical examination, his bowel sounds are absent, and he has marked tenderness in the right lower quadrant with guarding. The remainder of the abdominal exam is negative. Laboratory values reveal a leukocytosis with a left shift. What is the most likely initiating event for his acute condition?
- (A) Lymphoid hyperplasia
 - (B) Fecalith
 - (C) Parasitic infection
 - (D) Enlarged mesenteric lymph nodes
 - (E) Foreign body ingestion
2. A 50-year-old woman undergoes screening colonoscopy. She is asymptomatic. During the procedure, she is found to have a dark discoloration of the entire colon with lymph follicles shining through as pale patches. What is the most likely underlying etiology?
- (A) Drinking lots of prune juice
 - (B) Colon cancer
 - (C) Laxative abuse
 - (D) Normal anatomic variation
 - (E) Inflammatory bowel disease (IBD)
3. An 88-year-old man with Parkinson's disease and chronic obstructive pulmonary disease (COPD) is brought to the emergency department from a skilled nursing facility because his nurse noticed bright red blood in his stool. His medications include hydrochlorothiazide, metformin, levodopa, salmeterol, and docusate. On admission, he is afebrile with normal blood pressure and pulse. Nasogastric (NG) tube aspiration returns yellow bile. Colonoscopy shows bright red blood within the colon and multiple diverticula, but due to the large amount of stool and blood clots, no active bleeding sources are able to be seen. He continues to have blood per rectum over the next hour. Blood pressure is 120/70 mmHg and heart rate is 90/min. Which of the following is the most appropriate next step in management?
- (A) Exploratory laparotomy
 - (B) Transfuse two units of packed red blood cells
 - (C) 99mTc red blood cell (RBC) scintigraphy
 - (D) Esophagogastroduodenoscopy (EGD)
 - (E) Omeprazole and antibiotics
4. A 62-year-old female arrives to the emergency department with acute abdominal pain. She has a past medical history significant for diverticulitis. She is diagnosed with uncomplicated diverticulitis and managed with bowel rest and antibiotics. A year later, she has another episode of diverticulitis that was again successfully managed on an outpatient basis. Which of the following is this patient at higher risk for developing?
- (A) Crohn's
 - (B) Ulcerative colitis
 - (C) Colon cancer
 - (D) Anal cancer
 - (E) Stricture formation

5. A 90-year-old man with Alzheimer's disease arrives from a nursing home with abdominal distention and pain for the past 12 hours. He takes hydrochlorothiazide, donepezil, aspirin, and docusate. His physical exam reveals a temperature of 38.8 °C, blood pressure 90/70 mmHg, and pulse 112/min. His abdomen is rigid and diffusely tender with rebound and guarding. Laboratory examination is significant for WBC of $15 \times 10^3/\mu\text{L}$ (normal $4.1\text{--}10.9 \times 10^3/\mu\text{L}$), BUN of 25 mg/dL (7–21 mg/dL), and creatinine of 1.8 mg/dL (0.5–1.4 mg/dL). Abdominal x-ray shows a markedly distended colon with a bent inner tube sign. Following IV fluids and antibiotics, what is the best next step in management?
- (A) Decompression with colonoscopy
 - (B) CT scan of the abdomen and pelvis
 - (C) Exploratory laparotomy
 - (D) Placement of a rectal tube alone
 - (E) Admit to hospital for close observation
6. An 88-year-old woman with multi-infarct dementia undergoes a coronary artery bypass with the left internal mammary artery used as a conduit for three-vessel disease. Her operation is a success, and she is transferred to the ICU to recover. She is receiving opioids for pain relief. Over the next few days, she develops a markedly distended abdomen with no bowel sounds, pain, or rigidity. She has also not had a bowel movement for the past 48 hours. Rectal examination does not demonstrate any retained stool. Abdominal x-ray demonstrates a markedly distended colon with gas in the rectum, without air fluid levels. What part of the large bowel is the most likely to perforate?
- (A) Cecum
 - (B) Transverse colon
 - (C) Sigmoid colon
 - (D) Rectum
 - (E) There is very little risk of perforation
7. A 75-year-old man arrives to the emergency department with abdominal pain. He has never experienced this before but reports having left-sided abdominal pain over the last 2 days that is relieved temporarily after defecation. He has a temperature of 38.5 °C with a blood pressure of 142/88 mmHg and pulse of 88/min. His laboratory examination is significant for a WBC of $14 \times 10^3/\mu\text{L}$ (normal $4.1\text{--}10.9 \times 10^3/\mu\text{L}$) with 10% bands. CT imaging reveals focal sigmoidal wall thickening with significant paracolic inflammation. He was treated in the hospital for 3 days and discharged home without complications. Which of the following is the most appropriate follow-up option?
- (A) High-fiber diet alone
 - (B) CT scan 2 weeks after resolution
 - (C) Elective sigmoid colectomy
 - (D) Barium enema
 - (E) Colonoscopy
8. A 28-year-old woman presents to the emergency department because of abdominal pain that started 2 hours ago. She has nausea and vomited twice in the last hour. She reports that the pain is predominantly in the right lower quadrant (RLQ). On physical exam, her blood pressure is 120/60 mmHg, heart rate is 100/min, and she is afebrile. She is very tender at McBurney's point and has pain on passive extension of the right hip. Her WBC is $14 \times 10^3/\mu\text{L}$ (normal $4.1\text{--}10.9 \times 10^3/\mu\text{L}$), hemoglobin is 12 g/dL (12–15.2 g/dL), hematocrit is 36% (37–46%), and platelet count is 250,000 u/L (140–450,000 u/L). Her urinalysis shows 1+ white blood cells. Which of the following is the best next step in management?
- (A) Admit for observation
 - (B) CT scan of the abdomen
 - (C) Laparoscopic appendectomy
 - (D) B-hCG
 - (E) Oral antibiotics covering gram-negative flora

9. A 38-year-old male presents with history and exam suggestive of acute appendicitis and undergoes laparoscopic appendectomy. At surgery the terminal ileum and cecum appear to be red and inflamed. The appendix is removed uneventfully. Final pathology of the appendix demonstrates no evidence of acute appendicitis. Two weeks later, he presents back to the emergency department with feces draining from his right lower quadrant wound. Which of the following is the most likely explanation for why the drainage may not spontaneously stop?
- (A) A distal colonic obstruction
 - (B) Chronic inflammation
 - (C) An occult intra-abdominal abscess
 - (D) A retained sponge in the abdomen
 - (E) A missed malignancy
10. Which of the following is most likely to require *urgent* colectomy?
- (A) Cecal volvulus
 - (B) Sigmoid volvulus
 - (C) Acute diverticulitis
 - (D) Cecal adenocarcinoma
 - (E) Pseudomembranous colitis
11. A 55-year-old man starts a new security job that requires a physical exam by a doctor. He has no past medical history, and everyone in his family is healthy. He has a well-balanced diet and exercises every day. He is evaluated during a routine examination which includes a discussion of health maintenance issues. He is surprised to hear that it is recommended for a man of his age to get a colonoscopy. He asks if there are any other options available. Which of the following is an appropriate recommendation with respect to this health maintenance screening strategy?
- (A) Fecal occult blood test (FOBT) every 5 years
 - (B) Annual rectal examination
 - (C) Flexible sigmoidoscopy every 5 years + FOBT every 3 years
 - (D) Annual CT colonography
 - (E) Annual CEA levels
12. A 50-year-old man comes to the doctor complaining of painful defecation. On occasion, blood is found on the toilet paper after wiping. He has been experiencing this problem for months but felt too embarrassed to seek medical attention. He has a history of constipation and has tried multiple stool softeners but to no avail. Rectal examination shows enlarged anal papillae with an edematous and hypertrophic skin tag in the posterior anal midline, most suggestive of a chronic fissure. He is referred to a surgeon and scheduled to undergo a lateral internal sphincterotomy. What is the most common complication of this procedure?
- (A) Persistent bleeding
 - (B) Urinary retention
 - (C) Fecal incontinence
 - (D) Fistula formation
 - (E) Nonhealing of fissure
13. A 44-year-old man presents with right lower quadrant pain without rebound, nausea, and vomiting. CT scan shows bowel wall thickening near the ileocecal valve. He is scheduled for an appendectomy. Final pathology confirms acute appendicitis. In addition, an incidental 2.5 cm carcinoid tumor is found at the tip of the appendix. What is the most appropriate next step in management?
- (A) Observation
 - (B) Colonoscopy within the next 6 months
 - (C) Upper GI study with small bowel follow through
 - (D) Chest x-ray
 - (E) Right hemicolectomy

14. A 64-year-old male returns for follow-up 6 months after successful sigmoid colectomy for colon cancer. Which of the following can lead to a falsely elevated serum CEA level?
- (A) Chronic wound infection
 - (B) Smoking
 - (C) Hyperglycemia
 - (D) Age
 - (E) Postoperative chemotherapy
15. A 55-year-old male has been receiving serial ultrasound examinations to follow his abdominal aortic aneurysm (AAA). Over the past year, the aneurysm has rapidly enlarged to 5.8 cm, and he undergoes endovascular abdominal aortic aneurysm repair (EVAR). The operation itself is uneventful. However, on postoperative day 1, the patient develops a low-grade fever, left lower quadrant pain, and diarrhea that appears to be blood tinged. On physical examination, he has mild to moderate tenderness in the left lower quadrant without rebound or guarding. What is the next step in the workup?
- (A) CT scan of the abdomen and pelvis with oral and IV contrast
 - (B) Exploratory laparotomy
 - (C) Formal mesenteric arteriography
 - (D) Flexible sigmoidoscopy
 - (E) Abdominal ultrasound
16. A 30-year-old man with colon cancer secondary to familial adenomatous polyposis (FAP) arrives for follow-up after receiving a total proctocolectomy with end ileostomy. He was found to have colon cancer after presenting at the age of 27 with unexplained rectal bleeding, diarrhea, and abdominal pain. Subsequent colonoscopy found multiple adenomatous polyps in his colon. He has a 5-year-old son, who is screened and is positive for the APC gene. What is the recommended screening for his son?
- (A) Colonoscopy starting at age 20
 - (B) Flexible sigmoidoscopy starting at age 10
 - (C) Flexible sigmoidoscopy starting at age 17
 - (D) Annual fecal occult blood test
 - (E) Annual barium enema
17. A 66-year-old male presents to the emergency department with a large volume of maroon-colored stools combined with red blood. His blood pressure is 100/60 mmHg, and heart rate is 120/min. Physical examination is unremarkable. Two large bore IVs are inserted and 2 liters of normal saline are given, after which the patient's vital signs normalize. Laboratory tests are sent, including a type and cross. What is the next step in the management?
- (A) Administer two units of O-negative blood
 - (B) Esophagogastroduodenoscopy (EGD)
 - (C) Colonoscopy
 - (D) Exploratory laparotomy
 - (E) Place central venous line
18. A 27-year-old man arrives to the emergency department complaining of bloody diarrhea and rectal urgency. He reports a normal appetite and has not lost any significant weight. After initial workup yields no findings, he is referred to a gastroenterologist for a colonoscopy. He is found to have pseudopolyps in his colon, and subsequent biopsy results confirm ulcerative colitis. He is started on corticosteroids and sulfasalazine, which is able to control his symptoms. Which of the following is true regarding colon cancer and screening in patients with ulcerative colitis?
- (A) Screening for colon cancer is not necessary
 - (B) Screening colonoscopy 8 years after disease onset with random biopsies
 - (C) Screening colonoscopy 8 years after disease with biopsy only if a suspicious polyp is seen
 - (D) Screening colonoscopy annually once diagnosis is established
 - (E) The risk of colon cancer is much less than with Crohn's

19. Endocarditis secondary to which of the following organisms is associated with colon cancer?
- (A) *Streptococcus bovis*
 - (B) *Clostridium septicum*
 - (C) *Streptococcus bovis* and *Clostridium septicum*
 - (D) *Diphyllobothrium latum*
 - (E) *Cryptococcus neoformans*

Answers

1. Answer A
Acute appendicitis is triggered by an obstruction of the appendiceal lumen. In adults the obstruction is most commonly caused by a fecalith (B). However, in children the obstruction is most often due to lymphoid hyperplasia within the appendix that may be triggered by an antecedent viral infection. Thus, patients may have a history of a recent viral infection prior to the acute appendicitis. Parasites, such as pinworm, and foreign body ingestion can rarely obstruct the appendiceal lumen and cause appendicitis (C, E). Acute mesenteric adenitis can mimic acute appendicitis (D). However, this is less common, and the vast majority present with mild diffuse abdominal pain as opposed to localized pain and tenderness at McBurney's point.
2. Answer C
This patient most likely has *melanosis coli*, also known as *pseudomelanosis coli*, secondary to laxative abuse. This benign condition is often discovered incidentally during colonoscopy and is considered a disorder of pigmentation of the colonic wall. The dark discoloration is a result of lipofuscin in macrophages, and not melanin. Patients can be asymptomatic or sometimes present with watery or nocturnal diarrhea. The other options are not consistent with the colonoscopic findings (A–B, D). IBD may show cobblestone mucosa, strictures, and/or pseudopolyps and a colon devoid of haustra (E).
3. Answer C
This patient is suffering from a lower GI bleed (LGIB). The risk of LGIB increases with age, a trend that is driven by the age-associated increase in the incidence of diverticular hemorrhage, which is the most common cause of LGIB. Colonoscopy is indicated, but in the acute bleed setting may not demonstrate the source of bleeding. Since the bleeding has not stopped and has not been localized, additional studies are indicated. Options include radiolabeled RBC scintigraphy or angiography. Scintigraphy has the advantage of being noninvasive, is more sensitive (it detects less brisk bleeding), and can be easily repeated. It is utilized when the patient is actively bleeding (provided they are stable) when colonoscopy cannot identify the source. Exploratory laparotomy would be indicated if the patient is hemodynamically unstable from a massive LGIB as there is no time to identify the exact source (A). Transfusion is not indicated given that the patient responded to IV fluids (B). EGD would be the first-line study for an upper GI bleed (D). Omeprazole and antibiotics would be indicated in a patient suspected of having ulcers secondary to *H. pylori* (E).
4. Answer E
One of the complications that may develop from recurrent bouts of diverticulitis includes stricture formation. In response to repeated inflammatory insults to the colon, a portion may become scarred and subsequently narrowed. These patients can present with a decreased caliber of stool, ileus, or bowel obstruction. Barium enema or colonoscopy is often used to diagnose patients. Diverticulitis does not increase the risk of developing inflammatory bowel disease, colon, or anal cancer (A–D).

- ✓ 5. Answer C
Sigmoid volvulus occurs in debilitated and/or psychiatric patients. The twist in the colon leads to a closed loop obstruction which, if left untreated, leads to colonic ischemia, sepsis, and eventual colonic gangrene and perforation. Patients present with abdominal distention, pain, constipation, and vomiting. X-ray films may show an air filled closed loop of massively distended colon, referred to as a "bent inner tube" or "coffee bean" sign. Most patients can be managed by decompression with colonoscopy. However, this patient demonstrates evidence that the colon is already ischemic/gangrenous (fever, tachycardia, hypotension, peritonitis, leukocytosis). Thus, colonic decompression is contraindicated (A). Following fluid resuscitation and antibiotics, the patient requires urgent exploratory laparotomy with sigmoid colon resection and proximal colostomy. Similarly, with peritonitis and the classic plain x-ray finding, CT scan is unnecessary and in fact may cause renal injury given his pre-renal azotemia (B). Placing a rectal tube and admitting to the hospital without surgery would not be appropriate (D–E).
- ✓ 6. Answer A
Ogilvie's syndrome is a pseudo-obstruction of the colon that is associated with bed-ridden, neurologically impaired or older patients, opiate use, recent surgery, trauma, or infection. The mechanism for this colon dysfunction is unknown. X-ray films will predominantly show a markedly colon without evidence of a bowel obstruction. Management consists of removing any drugs that may interfere with gut motility (e.g., opiates) and replacement of electrolytes (especially potassium). A colon larger than 10 cm is at risk for perforation and requires decompression with neostigmine and/or colonoscopy. Due to the law of Laplace (tension = [pressure × radius]/wall thickness), the cecum, being the part of the colon with the largest diameter and thinnest wall, is the most common site for perforation (B–E).
- ✓ 7. Answer E
Diverticula occur as a result of herniation of mucosa through the colonic wall at sites where small arterioles (vase recta) enter the muscular layer. The incidence of diverticula increases with age, and it is believed to be present in 35% of the population. When diverticula get infected (diverticulitis), often on the left side, patients can present with fever, leukocytosis, and left lower quadrant pain that may be temporarily relieved following defecation. This patient has a moderate case of diverticulitis given the CT findings of significant inflammation in the sigmoid colon, fever, and leukocytosis. Treatment initially consists of bowel rest and IV antibiotics. Patients with acute diverticulitis should receive a follow-up colonoscopy within 6–8 weeks to rule out malignancy (as the CT cannot readily distinguish diverticulitis from colon cancer). Colonoscopy should not be performed during the same hospitalization as the insufflation of air may lead to free perforation. Barium enema (with or without sigmoidoscopy) is not a recommended screening tool for colon cancer (D). In addition to a colonoscopy, a fiber-rich diet should be encouraged for all patients with diverticulitis to reduce the incidence of diverticula (A). Follow-up CT scan is unlikely to provide any additional information other than confirming diverticula (B). Surgery is recommended for cases with significant complications (e.g., complete obstruction, free perforation with diffuse peritonitis) and those that have failed medical management (C).
- ✓ 8. Answer D
The differential diagnosis of RLQ pain in women is more extensive than for men and should include ruptured ectopic pregnancy, ruptured cyst, ovarian torsion, and pelvic inflammatory disease. B-hCG test should always be ordered in a woman of childbearing age with abdominal pain to rule out pregnancy. If positive, a ruptured ectopic pregnancy should be high on the differential. Although the patient presented has McBurney's point tenderness and an elevated WBC, laparoscopic appendectomy would not be recommended as of yet until the B-hCG is obtained (C). Broad-spectrum IV antibiotics covering anaerobes and gram-negative flora would be appropriate to

start while awaiting B-hCG (E). In addition, in women, ultrasonography is highly useful to rule out the aforementioned differential. CT scan is not necessary to confirm the diagnosis of acute appendicitis (B). Rather it is used if the diagnosis is in question. CT scan demonstrating large hemoperitoneum and normal appendix in a hypotensive woman is concerning for a ruptured ovarian cyst. Admission for observation would not be appropriate for the above patient (A). Do not assume that pyuria rules out appendicitis as an inflamed appendix can commonly cause sterile pyuria, particularly in the case of a retrocecal appendix. Retrocecal appendicitis will present with Psoas sign (pain on passive extension of the right hip).

✓ 9. Answer B

A rare complication after appendectomy is a cecal fistula. The findings on laparoscopy (inflamed terminal ileum and cecum) combined with a normal appendix indicate that the patient's actual diagnosis is likely Crohn's which can mimic appendicitis (in this setting, it is termed *regional enteritis*). If regional enteritis is found instead of appendicitis at the time of laparoscopy, the appendix is removed even if it looks normal, provided the cecum is not involved in the inflammation. This prevents confusion in case the patient presents again with RLQ pain in the future. However, if the cecum is also inflamed in the setting of regional enteritis, the appendix should not be removed, as there is a risk that the stump of the appendix will blow out and form a fistula (as in the present case). Conditions that prevent fistulas from spontaneously closing can be remembered by the acronym "HIS FRIEND": High-fistulas output (>500 ml/day), inflammatory bowel disease, short fistula (<2.5 cm), foreign body, radiation, infection, epithelialization, neoplasm, and distal obstruction. High-output fistulas (>500 ml/day) are less likely to close than low-output fistulas. In general, colonic fistulas are low output, while small bowel fistulas are high output. Although all the choices above can all contribute to non-closure of a fistula, chronic inflammation (from inflammatory bowel disease) is the most likely one in this case.

✓ 10. Answer A

Cecal volvulus is due to a failure of fixation of the right colon (due to a congenital malrotation). Once diagnosed, treatment is to perform an urgent right colectomy, as it does not respond well to nonoperative management (it cannot effectively be detorsed with colonoscopy). Provided there is no evidence of ischemic bowel, sigmoid volvulus is most often managed with initial endoscopic decompression, followed by a semi-elective sigmoid colectomy after performing a bowel prep (B). Most patients with diverticulitis can be managed via a combination of antibiotics, bowel rest, and subsequent dietary modification (high fiber) (C). Due to the large diameter of the cecum and the liquid nature of stool at that location, cecal adenocarcinoma rarely presents with a large bowel obstruction (which would be the main indication for urgent surgery with colon cancer) (D). Rather, it presents most commonly with iron deficiency anemia. Pseudomembranous colitis, due to *Clostridia difficile*, is successfully managed in most patients with oral metronidazole (and stopping the offending antibiotics) (E). Other antibiotic choices include vancomycin and fidaxomicin. In rare cases, the colitis can progress to life-threatening sepsis (termed *toxic colitis*) that requires emergency total colectomy.

✓ 11. Answer C

A colonoscopy is considered the gold standard because it can visualize the entire colon, identify small polyps/adenomas, and take biopsies. However, not all patients are comfortable with this test and could benefit from learning about other options. Flexible sigmoidoscopy every 5 years with FOBT every 3 years is an alternative screening modality recommended by the American College of Radiology Joint Task Force. An annual FOBT (not every 5 years) is another appropriate alternative, but abnormal results should always be followed up with a colonoscopy (A). Annual rectal examination is not considered adequate screening because of poor sensitivity (9%) (B). CT colonography done every 5 years (not annually) is as likely as colonoscopy to detect

lesions 10 mm or larger but may be less sensitive for smaller adenomas (D). Serum CEA level is used as a marker for colon cancer recurrence following surgery; however, CEA level lacks both sensitivity and specificity (it is elevated with other cancers and with benign conditions), such that it should never be used for colon cancer screening (E).

✓ 12. Answer B

Anal fissure is the most common cause of minor painful rectal bleeding (hemorrhoids usually cause minor painless bleeding). To get an anal fissure, one needs two things: anal trauma (from hard stools) and a hypertonic/hypertrophied internal sphincter. The hard stool tears the anoderm, most often in the posterior midline (most vulnerable to damage due to a relatively diminished blood supply). Patients typically present with painful defecation and blood found on tissue after wiping. Chronic fissures become deeper and will have enlarged anal papillae with hypertrophic and edematous skin tags (sentinel pile). Medical management includes sitz baths (relaxes sphincter), fiber, and stool softeners. If this treatment fails, diltiazem (preferred) or nitroglycerin ointment (limited by side effect of headaches) is considered next. Botulinum toxin (injected into the internal sphincter) may also be attempted. Patients that fail medical therapy can be considered for surgical treatment with lateral internal sphincterotomy, which is able to cure 95% of cases (E). The most common overall complication is urinary retention shortly after the procedure. The most serious complication is fecal incontinence (occurs with iatrogenic resection of the external anal sphincter) and ranges from 5% to 15% (C). Persistent bleeding is uncommon (A). Fistula formation is more common in patients with underlying Crohn's (C).

✓ 13. Answer E

It is imperative that following appendectomy, the appendix is inspected and histologically examined by a pathologist as an appendiceal tumor is sometimes discovered incidentally. The most common appendiceal tumor is mucinous adenocarcinoma (it was previously thought to be carcinoid). In the case of adenocarcinoma of any size or location, a right colectomy is recommended. In the case of a carcinoid tumor, the majority of these are located at the tip of the appendix. For tumors ≥ 2 cm and located at the tip of the appendix or for tumors of any size located at the base of the appendix (thus, involving the margins), a right colectomy is indicated. Otherwise, no further treatment is needed. The other answer choices are not appropriate for a carcinoid tumor (A–D).

✓ 14. Answer B

Carcinoembryonic antigen (CEA) is a glycoprotein, which is present in normal mucosal cells, but increased amounts are associated with adenocarcinoma, especially colorectal cancer. The major role of CEA in colon cancer patients is to allow clinicians to monitor for recurrence after intended curative treatment. Typically, patients achieve normal levels about 4–6 weeks after surgical intervention. Smoking up to 4 hours prior to checking serum CEA can falsely elevate levels. CEA levels are also elevated with other cancers (e.g., medullary carcinoma of the thyroid, pancreatic, gastric cancer) as well as benign conditions (inflammatory bowel disease, pancreatitis and cirrhosis), but not with the other choices provided (A, C–E). It is recommended to counsel all patients to quit smoking as it can affect postoperative monitoring and improves overall health.

✓ 15. Answer D

Ischemic colitis is one of the complications that can occur after AAA repair. The etiology is thought to be due to the fact that the inferior mesenteric artery (IMA) is ligated (with open repair) or occluded (with endovascular repair). In the majority of patients, there is no consequence from ligating the IMA. Depending on collateral blood supply, the left colon may develop mucosal or full-thickness ischemia. Patients present with varying degrees of left lower quadrant pain, fever, diarrhea, or frankly bloody stool. Ischemic colitis is confirmed by flexible sigmoidoscopy that will demonstrate inflamed, friable mucosa, or full-thickness necrosis (bear in mind that a scope within the lumen

cannot necessarily determine full-thickness necrosis). Treatment of ischemic colitis begins with placing the patient NPO and administering IV fluids and broad-spectrum antibiotics. If there is evidence of sepsis and/or peritonitis, the patient will require exploratory laparotomy, colonic resection, and a proximal colostomy (B). Since the cause of the ischemic colitis (ligation of the IMA) is known and cannot be reversed, CT, formal mesenteric arteriography, and ultrasound are not helpful (A, C, E).

✓ 16. Answer B

Familial adenomatous polyposis (FAP) is an autosomal dominant condition in which patients develop hundreds to thousands of polyps in the colon, which if left untreated, has a 100% chance of developing into cancer by age 40. The mutation is in the adenomatous polyposis coli (APC) gene on chromosome 5 (5 letters in "colon"). A child who has a parent with the mutation has a 50% chance of inheriting the syndrome. Thus, APC gene testing is recommended. If the child tests positive, screening with flexible sigmoidoscopy should begin at age 10 (as polyps can develop even in the teen years) (C). Once a polyp is seen, surgery is recommended to remove the colon typically by age 20. Since the polyps begin on the left side of the colon, a full colonoscopy is not required for screening (A). Annual fecal occult blood tests or barium enemas are not adequate screening tools in FAP (D–E).

✓ 17. Answer B

The first step in the workup for GI bleeding is to determine if the source is the upper or lower GI tract. If the patient is vomiting blood or has coffee ground emesis, then the source is clearly an UGI one. Since a massive UGI bleed can cause bleeding per rectum, it is imperative that an UGI source is ruled out first when working up a patient with a massive lower GI bleed. This is achieved by performing an EGD. Previously, these patients received a nasogastric tube to examine the aspirate for blood. However, EGD is more sensitive to detect an UGI bleed and can serve as a therapeutic modality. Since the patient responded to a fluid challenge, a blood transfusion is not necessary (A). Colonoscopy is not yet indicated nor is surgery (C–D). A central venous line should be considered if ongoing massive fluids/blood are needed (E).

✓ 18. Answer B

Patients with inflammatory bowel disease are at increased risk of colon cancer. The risk is much greater for ulcerative colitis (UC) than with Crohn's and is related to the duration of illness and the extent of disease. For UC, the risk is low in the first 10 years of the disease (2–3%) but grows to 1–2% per year afterwards. UC patients should begin getting screened 8 years after disease onset and continue getting screened every 1–2 years after. *Random biopsies* are necessary in patients with UC undergoing screening with colonoscopy because in these patients, cancers do not follow the typical progression from polyp to cancer (A, C–E). A proctocolectomy removes the entire rectum and colon, which prevents patients with UC from developing cancer, and no further surveillance is required.

✓ 19. Answer C

Streptococcus bovis and *Clostridium septicum* are both associated with colon cancer. The clinical context *S. bovis* comes up in most often is in that of patients suffering from endocarditis. *C. septicum* can spread hematogenously to muscle tissue and is also associated with the concomitant presence of hematologic malignancy. All patients found to be infected with these organisms should be scheduled for a colonoscopy to rule out colorectal malignancy. *Diphyllobothrium latum* (fish tapeworm) and *Cryptococcus neoformans* have not been linked to an increased risk of developing colon cancer (D–E).

Neurosurgery

Richard G. Everson

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Neck Pain and Extremity Weakness Following Trauma

Richard G. Everson, Jose Manuel Sarmiento, and Isaac Yang

Case Study

A 25-year-old man was snowboarding down a slope and attempted to perform a trick off a ramp. He miscalculated the jump and landed directly on his head, without a helmet. He denied any loss of consciousness but immediately had difficulty moving his arms and legs. The ambulance crew placed him supine on a board with a hard cervical collar and blocks. In the emergency

department, he is alert and oriented to person, place, and time, but he complains of severe neck pain. His heart rate is 80 beats/min, blood pressure is 130/85 mmHg, respiratory rate is 13/min, and temperature is 37.4 °C. He has 2/5 strength in his upper and lower extremities. He reports decreased sensation to pinprick and cold packs in all extremities but has preserved sensation to

deep touch and pressure throughout the body. He has nonsustained clonus and brisk reflexes in his biceps, brachioradialis, triceps, patellar tendons, and Achilles tendons. His big toe points upward with all other toes fanning out when the sole of his foot is stimulated with a blunt instrument. Rectal examination reveals preserved anal tone. His imaging is shown below (■ Fig. 28.1).

■ Fig. 28.1 a Lateral radiograph and b computed tomographic scan. (Reprinted from Vollmer et al. (2011). Copyright 2011, with permission from Elsevier)



Diagnosis

What Is the Differential Diagnosis for Cervical Spine Injury?

■ Table 28.1

Diagnosis	History and physical
Complete spinal cord injury	Complete loss of motor and sensory function (>3 segments) below level of lesion, including in the perineal and anal regions, in the absence of spinal shock
Brown-Sequard syndrome	Ipsilateral motor weakness with associated upper motor neuron signs (spasticity, hyperreflexia, clonus, and positive Babinski's sign) and touch/proprioception loss below the level of the injury; also, contralateral loss of pain and temperature sensation beginning one or two dermatome levels below the level of the injury

■ Table 28.1 (Continued)

Diagnosis	History and physical
Central cord syndrome	Weakness and loss of sensory function in the upper extremity and proximal leg muscles; distal lower extremities are typically spared
Anterior spinal artery syndrome	Paraplegia (quadriplegia if higher than C7) and loss of pain and temperature sensation; the posterior columns are unaffected, leading to preserved two-point discrimination, deep touch/pressure, vibration, and proprioception

What Is the Most Likely Diagnosis?

Anterior spinal artery syndrome due to burst fracture dislocation at C5. This is an *incomplete* spinal cord injury because the patient has some motor and sensory function in his extremi-

ties, as well as preserved anal tone. The patient's pertinent neurological examination findings (e.g., bilateral loss of motor, pain, and temperature with preserved deep touch, and pressure throughout the body) are consistent with an anterior cord syndrome with associated myelopathic signs. Radiographic studies show evidence of a burst fracture at the C5 level. Additionally, he has signs of upper motor neuron dysfunction (Babinski's sign). The patient does not show evidence of spinal shock (no flaccid paralysis in extremities and reflexes are present) or neurogenic shock (no hypotension or bradycardia).

History and Physical

What Are the Most Common Cervical Spinal Levels Involved After Trauma?

The most common level of cervical vertebral fracture is C2 (approximately 1/3rd of all C2 fractures are odontoid fractures) followed by C6 and C7. The most common level of subluxation injury is the C5–C6 interspace, which is the area of greatest flexion and extension in the cervical spine.

What Dermatome Level Supplies the Shoulders? What Must You Remember About the Dermatome Map When Testing Sensation on the Chest?

The shoulders are supplied by C4 (■ Table 28.2). When testing sensation on the chest, remember that there is a skip from C4 to T2, with C5 through T1 represented in the upper extremities.

Watch Out

A dermatome is a sensory region of the skin innervated by a nerve root.

Why Is It Important to Check Deep Tendon Reflexes?

Patients with injured nerve roots can have abnormal deep tendon reflexes (■ Table 28.3). Some patients with acute spi-

■ Table 28.3 Deep tendon reflexes

Reflex	Involved nerve root(s)
Biceps	C5/C6
Brachioradialis	C6
Triceps	C7
Patellar tendon (knee jerk)	L4
Achilles tendon (ankle jerk)	S1

nal cord injuries may initially have completely blunted reflexes during the acute stage of spinal shock but later develop hyperactive and brisk reflexes as the inhibitory forces from upper motor neurons are lifted.

How Are Deep Tendon Reflexes Graded?

These are graded as 0 to 4+ with 2+ *being normal*. 0 is no response, while 1+ is a sluggish one. A reflex that is more brisk than usual is 3+ and those with a clonus present are 4+.

Clinically, What Is the Difference Between a Complete and Incomplete Spinal Cord Injury?

Patients with complete spinal cord injuries have no motor and sensory function below the level of injury, whereas those with incomplete spinal cord injuries have some residual function below the injury level.

What Are the Devastating Clinical Examination Findings in Patients with Complete Spinal Cord Injury in the High Cervical Cord (at or Above C3)?

Inability to breathe due to diaphragmatic paralysis, as well as paralysis of all four limbs. The phrenic nerve originates from the C3 to C5 spinal nerves.

Watch Out

Remember: C3, C4, and C5 keep the diaphragm alive!

■ Table 28.2 Common dermatomal levels

Anatomical site	Dermatomal level
Shoulders	C4
Nipples	T4
Umbilicus	T10
Knees	L4
Perianal region	S4–S5

What Is the Term for Sensory or Motor Dysfunction Caused by Pathology of a Nerve Root? What Are the Clinical Signs and Symptoms Associated with This Disorder?

Radiculopathy. The main symptom associated with radiculopathy is a burning, tingling pain that radiates down the

limb. Clinical signs of radiculopathy include lower motor neuron signs such as loss of reflexes, weakness, and diminished sensation along dermatomal distributions.

What Is the Term for Sensory or Motor Dysfunction Caused by Pathology of the Spinal Cord? What Are the Clinical Signs and Symptoms Associated with This Disorder?

Myelopathy. Patients experience intermittent neck pain that radiates into the shoulders or occiput. Clinical findings of myelopathy result from a spinal cord injury and include bilateral upper motor neuron signs (■ Table 28.4) such as diffuse hyperreflexia, weakness and numbness in the extremities, and upward-going toes (Babinski's sign).

Watch Out

Babinski's sign can be a normal finding in infants as old as 2 years.

Pathophysiology

What Is the Difference Between Spinal Shock and Neurogenic Shock?

Spinal shock is not a true form of shock. It is a term used for a temporary (1 day to a few weeks), concussive-like syndrome associated with flaccid paralysis below the level of injury, with loss of all reflexes including urinary and rectal tone (loss of *bulbocavernosus reflex*). Neurogenic shock is a hemodynamic state wherein sympathetic outflow through the spinal cord has been disrupted. The loss of sympathetic tone results in vasodilation, bradycardia, and dangerous hypotension. Neurogenic shock is typically associated with more severe spinal cord injuries (typically above T6). A patient may have both neurogenic and spinal shock present simultaneously.

■ **Table 28.4** Upper motor neuron (UMN) and lower motor neuron (LMN) signs

Sign	UMN lesion	LMN lesion
Weakness	Yes	Yes
Fasciculations	No	Yes
Atrophy	No	Yes
Tone	Increased	Decreased
Reflexes	Increased	Decreased
Babinski's sign (plantar reflex)	Yes	No
Hoffmann's sign	Yes	No
Clonus	Yes	No

Watch Out

In a paralyzed trauma patient, hypotension should be presumed to be due to bleeding (hypovolemic shock) until proven otherwise, especially if they are *tachycardic*. Also, keep in mind that the abdominal exam is unreliable.

In the Context of Trauma, Why Are Thoracic Spine Injuries Less Common Than Cervical Spine Injuries?

Thoracic vertebrae are more stable due to high facets and ribs that decrease motion. They also have more canal space because the thoracic spinal cord does not have anterior enlargements (as opposed to the cervical and lumbar spinal levels).

What Is Sacral Sparing? What Is Its Significance in the Setting of Spinal Shock?

Sacral sparing refers to the sparing of function at the sacral nerve level, such as intact anal sphincter or perianal sensation. When there is sacral sparing in a patient with spinal shock, the chance of functional neurological recovery is better compared to a situation where the sacral roots are affected.

What Are the Common Mechanisms for Neck Injuries?

Flexion, extension, axial loading (vertical compression), and rotational injuries

What Is Atlanto-Occipital Dislocation?

This occurs when the superior facets of the atlas vertebra lose their articulation with the occipital condyles at the base of the skull, resulting from ligamentous disruption between the occiput and the cervical spine.

Watch Out

Atlanto-occipital dislocation is the most unstable and dangerous injury of the cervical spine. Severe neurological morbidity and mortality are due to high cervical cord injury that can lead to quadriplegia, diaphragm paralysis, and cardiac arrest. Patients with *trisomy-21* (Down's syndrome) are at a particularly higher risk for this injury and should always be screened for atlanto-occipital instability prior to participating in any sports.

What Is the Pathophysiology of the Three Most Common Incomplete Spinal Cord Injuries?

Table 28.5

Syndrome	Comments
<i>Brown-Sequard syndrome</i>	Hemisection of the spinal cord, usually from penetrating trauma such as a gunshot or a stabbing, causing injury to the corticospinal tract (motor), posterior columns (proprioception, deep touch/pressure), and spinothalamic tracts (contralateral pain and temperature)
<i>Anterior cord syndrome</i>	Damage to the anterior two-thirds of the spinal cord classically due to severe flexion injury; this area receives its blood supply from the anterior spinal artery; the corticospinal and lateral spinothalamic tracts are affected bilaterally
<i>Central cord syndrome</i>	Damage to the central portion of the spinal cord classically associated with severe hyperextension injury; patients who present with central cord syndrome are often elderly and have preexisting cervical stenosis

Why Are the Distal Lower Extremities Typically Spared in Central Cord Syndrome?

This reflects the unique topographical organization of the spinal cord in which upper extremity motor function is represented at the medial aspects of the cord, while lower extremity motor function is represented at the lateral aspects of the cord. The central portion of the spinal cord is a vascular watershed zone that is more susceptible to injury and ischemia from edema. Thus, motor function and sensation in the distal lower extremities are spared.

Which Incomplete Cord Syndrome Carries the Best Prognosis for Recovery of Neurological Function, Bowel and Bladder Function, and Ambulatory Capacity?

Brown-Sequard syndrome

Which Incomplete Cord Syndrome Carries the Worst Prognosis for Functional Recovery?

Anterior cord syndrome (about 10% recover to ambulation)

What Spinal Cord Injury Can Occur After Surgery on the Thoracic Aorta?

Anterior spinal cord infarction (due to interruption of artery of Adamkiewicz, branch of anterior spinal artery). They may develop bilateral flaccid paralysis with loss of pain/temperature below the lowest level of infarction shortly after surgery.

Workup

How Do You Diagnose Spinal Cord Injuries and Cervical Vertebral Fractures?

Spinal cord injuries may be diagnosed with a thorough history and neurological examination. The diagnosis may be confirmed with the help of radiographic imaging modalities such as x-ray, CT scan, and MRI. The American Spinal Injury Association (ASIA) scale should be used for functional assessment.

What Are the NEXUS Criteria?

This is a validated tool to determine which adult trauma patients may have their C-spine cleared (cervical collar removed) without first obtaining imaging. Attempting such clearance is *contraindicated* if they have any of the following criteria (remembered as the *NSAID* mnemonic):

- Neurologic deficit
- Spinal tenderness
- Altered mental status
- Intoxicated
- Distracting injury

What Type of Imaging Should Be Obtained?

A high-quality CT scan is the imaging modality of choice in adults.

What if CT Scan Is Not Available? What About Children?

To clear the cervical spine radiographically by plain film x-rays, the craniocervical junction down through the C7-T1 junction must be evaluated. Three x-ray views should be obtained to view the cervical spine: anteroposterior (AP), lateral, and *open-mouth* (odontoid). If the above studies are normal but the patient remains symptomatic, oblique and swimmer's view (arm elevated above the head) x-rays may visualize areas not seen. Three x-ray views are considered in pediatric trauma patients <9 years old in lieu of CT to reduce radiation risk.

What Is the Indication for Ordering an MRI Scan of the Cervical Spine?

An MRI scan should be obtained in the following scenarios. In patients with neurologic deficits consistent with a spinal cord injury, and in those with concern for neck instability or C-spine fracture, the MRI is a useful adjunct to CT as it helps to detect injury to the spinal cord itself. It can show areas of contusion, edema, and hematoma within the spinal space and identify rupture of intervertebral disks. In patients with neck pain who have a negative CT, MRI is recommended as it can identify ligamentous injury. If the patient is obtunded (and thus not examinable) and the CT scan is negative, some advocate an MRI to assure that there is no injury (though this is controversial). MRI may detect abnormalities in patients with a normal CT, sometimes termed SCIWOCTET (see below). A concern for instability and/or fracture of the cervical spine should warrant further evaluation with a C-spine MRI.

What Is SCIWORA and SCIWOCTET?

SCIWORA is a term to describe “spinal cord injury without radiographic abnormalities” and is not typically used anymore. SCIWOCTET is a term to describe “spinal cord injury without computed tomography evidence of trauma”. Since the advent of high-quality CT and MRI imaging over the past 10 years, most of these injuries are now identified.

Watch Out

C2 is the most common level injured in the spinal cord.

Management

What Are the General Treatment Principles for Patients with Cervical Spine Injury?

- Transport the patient with a rigid cervical collar on a spine board for immobilization.
- Early closed reduction with tongs or halo traction devices is recommended for awake patients with obvious subluxation on imaging causing spinal cord compression.
- Avoid hypotension (SBP <90 mmHg), and maintain mean arterial pressure between 85 and 90 mmHg for 7 days after spinal cord injury. Maintain minimum blood pressure goals with intravenous fluids and vasopressors (phenylephrine or dopamine) to reduce secondary injury.
- Insert a Foley catheter to monitor urinary output and prevent bladder distention in case of neurogenic urinary retention secondary to spinal cord injury. Administer stool softeners to prevent severe constipation.

- Order venous thromboembolism prophylaxis (i.e., low-molecular-weight heparin, heparin) within 48 hours, maintain for 3 months.
- Restore spinal stability by external orthoses (cervical collars, cervicothoracic devices, and halo orthosis) or surgical reduction, decompression, and/or fusion.

Watch Out

Among trauma patients, those with spinal cord injury have the highest rate of venous thromboembolic events.

How Is Neurogenic Shock Treated?

Hypotension is treated with rapid infusion of crystalloid normal saline (0.9% NaCl). If intravenous fluids are inadequate to maintain organ perfusion, phenylephrine (alpha agent) is often used (but may cause reflex bradycardia). Norepinephrine (with both alpha and beta effects) may be better at addressing both bradycardia and hypotension. Bradycardia can also be treated with atropine or dopamine.

What Are the Goals of Management for Patients with Complete Spinal Cord Injuries or High Cervical Cord Injuries?

Spinal stabilization to facilitate nursing and rehabilitation. Surgical decompression aims to maintain and regain function in the uppermost section of the injured cord where an incomplete injury may exist. Nonsurgical care focuses on functional rehabilitation, prevention of decubitus ulcers, bowel and bladder management, and avoidance of pneumonia and deep vein thrombosis.

Why Is There a Lower Threshold for Surgical Intervention in Patients with Incomplete Spinal Cord Injury Versus Patients with Complete Spinal Cord Injury?

Expedient open or closed reduction and cord decompression in patients with incomplete spinal cord injury have a higher likelihood of maintaining or regaining neurological function.

What Are the General Indications for Emergent Surgery with Spinal Cord Injury?

- Unstable vertebral fracture
- Non-reducible spinal cord compression with deficit
- Ligamentous injury with facet instability
- Progressive neurologic deficit

Watch Out

Restoration of spinal stability is important to minimize the risk for secondary injury and to allow early mobilization.

Area of Controversy**Steroid Therapy for Acute Spinal Cord Injury**

According to the 2013 guidelines for the management of acute cervical spine and spinal cord injuries, administration of methylprednisolone for the treatment of acute spinal cord injury is not recommended. Methylprednisolone is not FDA approved for this application, and there is no Class I or Class II evidence supporting the clinical benefit of steroids in the treatment of acute spinal cord injury, despite several randomized controlled trials.

Areas Where You Can Get in Trouble**Complications with the Exposure of the Anterior Cervical Spine**

The most common complication of exposing the anterior cervical spine for decompressive surgery is recurrent laryngeal nerve injury. Injury to this nerve can paralyze the vocal cords and lead to a hoarse voice (unilateral nerve injury) and risk for airway obstruction (bilateral nerve injury). Patients may also have transient dysphasia and, rarely, perforation of the esophagus—a life-threatening condition due to the high risk of infection. Injuries of the carotid artery, jugular vein, and superior and inferior thyroid arteries are uncommon. Injury of the vertebral artery is a rare complication.

Impaired Upper Extremity Strength After Whiplash

Patients that experience whiplash may not have any acute symptoms, but <5% are at risk for post-traumatic syringomyelia which can develop within the following year. This occurs as a result of cerebrospinal fluid retention enlarging the central spinal cord canal. Post-traumatic syringomyelia can result in weakness of the upper extremities along with decreased pain/temperature sensation bilaterally.

Summary of Essentials**History and Physical**

- A thorough neurological examination is necessary for localization of spinal cord injuries.

- Complete spinal cord injury: no motor and sensory function below the level of injury.
- Incomplete spinal cord injury: some residual function below the level of injury
 - Brown-Sequard syndrome
 - Central cord syndrome
 - Anterior cord syndrome

Pathophysiology

- Spinal shock: temporary, concussive-like syndrome associated with flaccid paralysis below the level of injury with loss of all reflexes, as well as urinary and rectal tone.
- Neurogenic shock: a hemodynamic state wherein sympathetic outflow through the spinal cord has been disrupted, resulting in vasodilation, bradycardia, and dangerous hypotension.

Workup

- CT C-spine is useful for detecting vertebral fractures and identifying hematomas or disk fragments within the spinal canal.
- If CT cannot be obtained and in pediatric traumas, x-rays are appropriate: anteroposterior (AP), lateral, and open-mouth (odontoid).
- MRI is useful to detect injury to the spinal cord itself in patients with neurological deficits.

Management

- Rigid cervical collar on a spine board
- Early closed reduction with tongs or halo traction devices for awake patients with obvious subluxation on imaging causing spinal cord compression
- IV fluids to avoid hypotension
- Vasopressors (phenylephrine or dopamine) if neurogenic shock
- Foley catheter
- Stool softeners
- Venous thromboembolism prophylaxis

Complications

- Exposure of the anterior cervical spine
 - Injury to the recurrent laryngeal nerve, leading to a hoarse voice and risk of aspiration

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Loss of Consciousness Following Head Trauma

Isaac Yang and Richard G. Everson

Case Study

A 40-year-old male motorcyclist is brought to the emergency department by paramedics after rear-ending a car at highway speeds. He was wearing a helmet but was thrown from his motorcycle. He was initially awake in the field but then quickly became unconscious. His airway is patent, and his respirations are shallow and irregular. His

blood pressure is 190/90 mmHg, heart rate is 60/min, and respiratory rate is 20/min and irregular. In response to sternal rub, the patient moans and withdraws his right upper and lower extremity, but he does not move the left upper or lower extremity, and he does not open his eyes. His Glasgow Coma Scale (GCS) is 7. His right pupil is

6 mm and nonreactive, while his left is 3 mm and reactive to light. There is no obvious head injury or laceration. There is no discharge from the nose or ears; however, there is right hemotympanum. The oropharynx is clear. The remainder of the physical examination is normal.

Diagnosis

What Is the Differential Diagnosis for a Severe (GCS ≤ 8) Traumatic Brain Injury?

Table 29.1

Diagnosis	Pathophysiology	Comments
<i>Epidural hematoma (EDH)</i>	Laceration of middle meningeal artery by temporal bone fracture; blood accumulates between the dura and skull	Classic presentation: brief loss of consciousness, followed by a lucid interval, then a rapid decline in level of consciousness; better prognosis than subdural
<i>Subdural hematoma (SDH)</i>	Rupture of bridging veins resulting in the accumulation of blood between dura and arachnoid membrane	More likely to have associated brain parenchymal injury than epidural; acute and chronic forms; worse prognosis than epidural
<i>Intraparenchymal hematoma</i>	Hemorrhage occurs in area of contused brain parenchyma	More likely to occur in association with hypertensive hemorrhage or arteriovenous malformation than with trauma; bleeding may be delayed
<i>Diffuse axonal injury (DAI)</i>	Rotational acceleration and deceleration results in shearing of axons between the gray and white matter	DAI is typically the underlying injury in shaken baby syndrome
<i>Subarachnoid hemorrhage (SAH)</i>	Accumulation of blood in CSF-filled subarachnoid spaces; trauma is the most common cause but also can occur spontaneously when caused by aneurysm rupture or AVM	Patient complains of “worst headache of my life,” sudden onset thunderclap headache when associated with spontaneous forms (aneurysm and AVM)

CSF cerebrospinal fluid, AVM arteriovenous malformation

What Is the Most Likely Diagnosis?

This patient has sustained a severe traumatic brain injury (TBI) as evidenced by a GCS of 7 (eyes-1, verbal-2, motor-4). He likely has a right-sided EDH which is supported by evidence of a right temporal bone fracture (hemotympanum). He also displays the classic sequence for EDH: consciousness, a brief lucid interval, and then progression to coma. The patient has objective signs of intracranial hypertension (Cushing’s triad: hypertension, bradycardia, and irregular respiration) and uncus herniation, with a dilated nonresponsive right pupil and left-sided hemiplegia.

History and Physical

What Is the Definition of a TBI?

TBI results in a disruption of brain function. To meet the definition of TBI, at least one of the following criteria must be met: a period of loss of consciousness, loss of memory for events immediately before or after the accident, alteration in mental state at the time of the accident, and/or focal neurologic deficit.

How Do You Calculate the GCS?

The GCS (Table 29.2) is composed of three components: eye opening, verbal response, and motor response. By definition, a neurologically intact person has a GCS score of 15. A GCS score of 3–8 indicates severe TBI, 9–12 indicates moderate injury, and 13–15 indicates mild injury. There is a 28% probability of mortality associated with scores of 7 or 8.

Watch Out

A patient with a GCS of 8 or less is considered to be in a coma and mandates immediate establishment of an airway.

Watch Out

The GCS score should be frequently reassessed to determine if the patient’s TBI is worsening.

■ Table 29.2 Glasgow Coma Scale (GCS)

Eye opening	Best verbal response	Best motor response	Points
		Follows commands	6
	Oriented	Localizes pain	5
Spontaneous	Confused	Withdraws from pain	4
To voice	Inappropriate words	Decorticates posturing	3
To pain	Incomprehensible	Decerebrates posturing	2
None	None	None	1

What Non-head Trauma Factors Affect GCS?

The GCS can be temporarily lowered by alcohol and drug intoxication, seizures, sedatives, severe hypoxia, shock, and severe hypothermia.

What Are Raccoon Eyes? What Is Battle's Sign?

Raccoon eyes are bilateral periorbital ecchymosis. Battle's sign is retroauricular ecchymosis. These signs should raise the suspicion of a *basilar* skull fracture.

How Does the Physical Exam Help to Localize the Site of Intracranial Bleeding?

Paralysis generally occurs contralateral to the lesion, and abnormal pupillary findings will occur ipsilateral to the lesion. The above patient has a left hemiparesis and a blown pupil on the right, referring to a fixed and dilated pupil resulting from compression of the *oculomotor nerve* (cranial nerve III) by the uncus of the temporal lobe. This localizes the lesion to the right.

What if the Blown Pupil and the Posturing Are on the Same Side? How Do You Use These Findings to Lateralize the Suspected Lesion?

In about one out of five cases of uncal herniation, the paralysis occurs ipsilateral to the lesion (Kernohan syndrome). This occurs when the *contralateral* cerebral peduncle is displaced laterally against the *contralateral* tentorial incisura resulting in paralysis *ipsilateral* to the lesion, a false localizing sign. Thus, the pupil is a more reliable lateralizing sign than the motor exam. Remember *dot marks the spot*.

What Is the Implication of Abnormal Arm Flexion/Leg Extension with Pain Stimulation? Arm/Leg Extension?

Abnormal flexion in upper extremity and extension in lower extremity in response to painful stimuli is called *decorticate posturing*. Abnormal extension in upper and lower extremity in response to painful stimuli is called *decerebrate posturing*. These are primitive reflexes mediated by the brain stem when higher brain function is absent. While both are grave signs, decorticate posturing carries a better prognosis than decerebrate posturing.

How Does the Presentation of Chronic SDH Differ from Acute SDH?

Acute SDH typically presents within 72 hours of head injury. Chronic SDH can have a delayed onset even months later. Chronic SDH typically affects the elderly, as they have brain atrophy, allowing more room for a slow bleed to accumulate without elevating the ICP. The presentation is often insidious: gait abnormalities, decreased levels of consciousness, aphasia, cognitive dysfunction, memory loss, and/or personality changes.

Pathophysiology

What Is a Concussion?

This is a term used for a mild TBI that presents without identifiable abnormalities on standard structural imaging (CT and MRI). A concussion temporarily alters brain function by causing problems with memory, balance, coordination, and/or concentration. It may be associated with symptoms such as headaches, dizziness, confusion, personality changes, and irritability. Loss of consciousness is not required to establish the diagnosis of a concussion.

What Is Uncal Herniation?

Uncal herniation occurs when a space-occupying lesion above the tentorium displaces the uncus of the temporal lobe medially and inferiorly over the tentorial incisura impacting on the ipsilateral oculomotor nerve (cranial nerve III) and ipsilateral cerebral peduncle, which contains the corticospinal tract. This results in an ipsilateral blown pupil and contralateral paralysis.

What Is the Pathophysiology of an Epidural Hematoma?

Epidural hematoma is the accumulation of blood between the dura and skull. A temporal bone fracture from a head injury results in laceration of the middle meningeal artery

(most common source) resulting in an EDH. EDHs have a biconvex appearance on CT that *do not cross suture lines*. Because the hematoma is from an arterial source, it may expand rapidly leading to mass effect, which requires urgent surgical evacuation.

What Is the Implication of a “Lucid” Interval with Head Injury?

Initial loss of consciousness results from disruption of the reticular activating system (RAS), located in the brainstem. The second loss of consciousness results from the expanding hematoma and mass effect. The interval between the first and second LOC is called the lucid interval, which may last minutes to hours. This is classically seen in EDH.

What Is the Pathophysiology of an Acute Subdural Hematoma?

Acute subdural hematoma is the accumulation of blood between the dura and arachnoid membrane. It results from tearing of the bridging veins, which run from the cortex to the dural venous sinuses. SDHs have a crescent-shaped appearance on CT that can cross suture lines. The elderly, alcoholics, and patients on anticoagulation therapy are particularly susceptible. The force required to tear these veins is typically greater than for an epidural. As such, SDH is more often associated with parenchymal injury and therefore carries a worse prognosis (despite it being a venous bleed).

Watch Out

The relatively atrophic brain parenchyma in the elderly increases tension on bridging veins making them more susceptible to injury after head trauma.

What Is the Formula for Cerebral Perfusion Pressure?

Cerebral perfusion pressure (CPP) is the difference between mean arterial pressure (MAP) and intracranial pressure (ICP).

What Other Factors Affect Cerebral Perfusion Pressure?

Because the brain is encased by the rigid bony cranium, three components contribute to the ICP: brain tissue, cerebrospinal fluid (CSF), and cerebral blood. According to the Monro-Kellie doctrine, in order to maintain constant ICP, an increase in one must result in a decrease in the volume of the other two components. This may lead to complications such as reduced cerebral blood flow leading to brain ischemia.

What Is the Most Powerful Intracranial Vasodilator?

The most powerful vasodilator is blood CO₂ level.

Watch Out

A closed head injury does not cause hypovolemic shock. If a patient with TBI is hypotensive, search for sources of hypovolemic shock (in the abdomen/chest/pelvis). Hypotension in the presence of TBI significantly increases mortality, as does hypoxia. A goal SBP >90 mmHg and PaO₂ >60 mmHg should be maintained.

What Is the Pathophysiology of Cushing’s Triad?

Cushing’s triad or Cushing’s reflex is the physiologic response to increased ICP. In the presence of elevated ICP, systemic blood pressure increases in order to maintain cerebral perfusion pressure. The increased pressure results in negative feedback at the carotid sinus leading to bradycardia. The respiratory center is located in the medulla and will become impaired as a result of elevated ICP.

What Is a Coup vs. Contrecoup Injury?

Coup refers to injury to brain tissue directly below the skull at the point of impact. However, the force of impact may thrust the brain tissue against the skull on the opposite site and cause injury. This is referred to as the contrecoup injury. Thus, contusion may occur on opposite sides of the brain.

Initial Management

What Initial Management Is Recommended for the Above Patient?

Initial management of this patient should follow the ABCDE model of primary assessment. A GCS of ≤8 (as in the present patient) is an indication for intubation so as to protect the airway and assure optimal oxygenation and ventilation. Moreover, intubation and paralysis can help facilitate ICP management. It is essential to document a neurologic exam prior to paralysis and intubation (part of the secondary survey), as this information can be useful and will be unobtainable once the patient is sedated/paralyzed. Next, he should receive a non-contrast head CT with anticipation that expedient evacuation of a likely epidural hematoma will follow.

Watch Out

A non-depolarizing neuromuscular blocking drug (succinylcholine) is preferred during rapid sequence intubation over depolarizing neuromuscular blocking drugs (e.g., rocuronium) because the effect is short-lasting allowing for reassessment of GCS soon after intubation.

What Are the Indications for Head CT with TBI?

All patients with moderate (GCS 9–12) and severe (3–8) TBI should get a non-contrast CT scan including all patients with unresponsiveness, focal deficit, amnesia, altered or deteriorating neurological status, signs of skull fracture, or prior to general anesthesia for other procedures. Patients with mild brain injury who have certain risk factors (anticoagulation, alcohol abuse, elderly) should also undergo a CT scan.

Watch Out

Ketamine can increase ICP and is relatively contraindicated in the setting of TBI. Etomidate would be a better option during rapid sequence intubation.

Describe the Findings on Head CT Seen with EDH, SDH, and SAH Intraparenchymal Contusion

Table 29.3

Findings	Diagnosis
Hyperdense lens-shaped (■ Fig. 29.1) density adjacent to skull, <i>does not cross suture lines</i> and is usually associated with a skull fracture	Acute epidural hematoma
Hyperdense crescent-shaped (■ Fig. 29.2) density adjacent to brain parenchyma but not within sulci, crosses suture lines but not the falx	Acute subdural hematoma
<i>Isodense or hypodense</i> crescent-shaped density adjacent to brain parenchyma but not within sulci, crosses suture lines but not the falx, often presents with mass effect out of proportion to clinical findings	Chronic subdural hematoma
Hyperdense material adjacent to brain parenchyma tracing along gyri and sulci often in a coup, contrecoup pattern relative to injury	Traumatic subarachnoid hemorrhage
Hyperdense irregular lesions within brain parenchyma often in a coup, contrecoup pattern	Intraparenchymal contusion

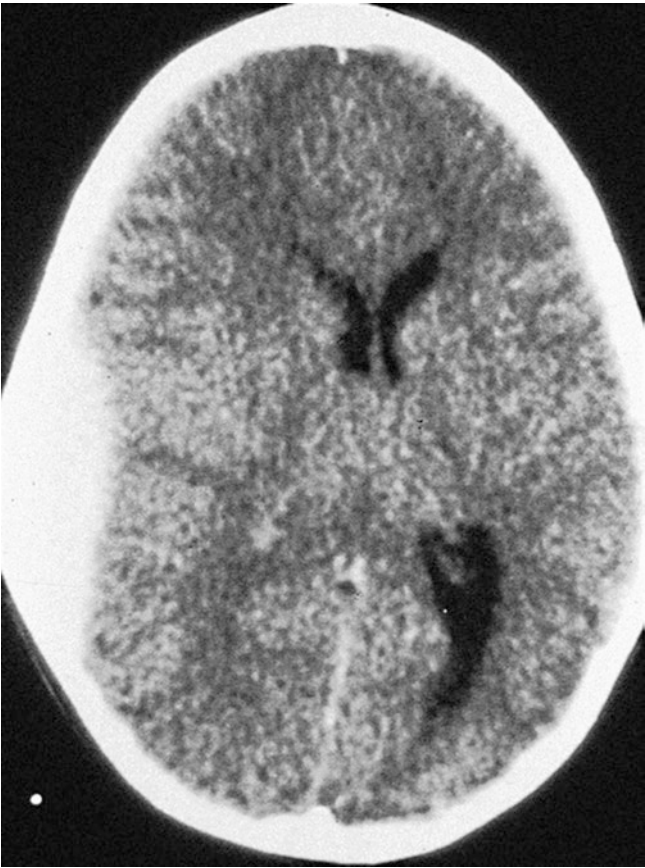


Fig. 29.1 Non-contrast head CT demonstrating an acute epidural hematoma. (From Hanley DF, et al. *Coma and intensive care neurology*. In: Rosenberg RN, editor. *Atlas of clinical neurology*. London: Current Medicine Group; 2003. Reprinted with permission from Springer Nature)

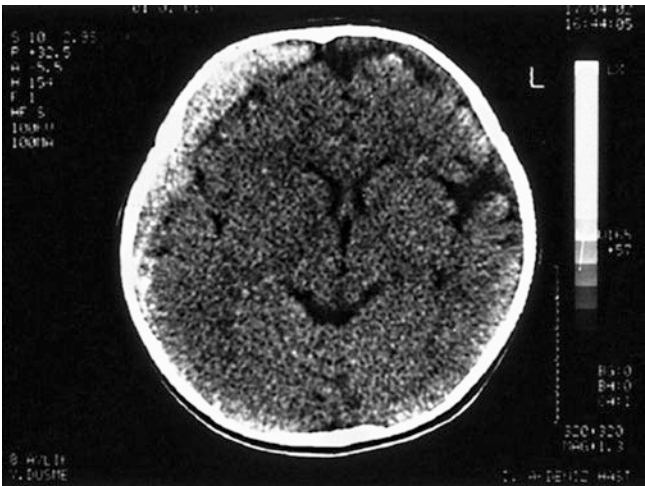


Fig. 29.2 Non-contrast head CT demonstrating an acute subdural hematoma. (From Erdogan B, et al. *Hemispheric cerebrovascular venous thrombosis due to closed head injury*. *Childs Nerv Syst*. 2004;20:239. ▶ <https://doi.org/10.1007/s00381-003-0845-7>. Reprinted with permission from Springer Nature)

What Are the Indications for ICP Monitoring?

Most patients with a significant TBI will meet one or more criteria for ICP monitoring. Normal ICP is typically between 5 and 15 mmHg. Treatment is indicated for pressures greater than 20 mmHg in adult patients and lower levels for children and infants. The preferred method of ICP monitoring in the setting of trauma is with a ventriculostomy tube connected to an external ventricular drain (EVD). This allows it to be used for diagnostic and therapeutic purposes (i.e., CSF drainage when ICPs become high). ICP monitoring is indicated for the following patients:

- Severe TBI (GCS score 3–8) with abnormal head CT
- Severe TBI (GCS score 3–8) with normal head CT but with any two of the following: hypotension (SBP <90 mmHg), posturing, or age ≥ 40
- When the neurological exam cannot be appropriately assessed due to sedation or anesthesia with suspicion of high ICP

Watch Out

Patients with severe TBI are at risk of developing disseminated intravascular coagulation because of the exposed underlying tissue factor of the injured brain parenchyma; be sure to follow coagulation labs and platelet count.

What Is the Role of Hyperventilation?

Prior to ICP monitoring, mild hyperventilation is indicated as a temporizing measure in a patient with radiographic (CT findings) or clinical signs of elevated ICP. If indicated, hyperventilation is initiated with a goal of PaCO₂ between 30 and 35 mmHg. This can temporarily lower blood CO₂ leading to cerebral vasoconstriction and a subsequent reduction in ICP. It is important to note that PaCO₂ should not be reduced below 30 mmHg as it may dangerously decrease cerebral blood flow and even mild hyperventilation should be discontinued once other methods of ICP control are started.

What Other Medical Treatment Options Are There for Intracranial Hypertension?

The head of the bed should be elevated to 30–45°. The cervical collar should be carefully loosened if restricting venous outflow. Hyperthermia should be treated if present. Mannitol is generally the first-line drug, as well as hypertonic saline (3% and higher). Finally, the patient can be paralyzed, and some advocate for therapeutic hypothermia. If ICP cannot be controlled with the above methods, a barbiturate coma or a decompressive craniectomy may be indicated.

Watch Out

Avoid Lactated Ringers in TBI. With a sodium content of only 130 meq/L, Lactated Ringers is slightly hypotonic.

How Does Mannitol Work?

Mannitol is an osmotic diuretic. Mannitol increases the tonicity of the extracellular space, which causes a shift of water from the intracellular space (brain parenchyma) to the extracellular space, reducing ICP. Initially, it expands the plasma volume and reduces blood viscosity, which increases cerebral blood flow (and O₂ delivery).

Watch Out

Mannitol should be avoided in patients with hypotension or hypovolemia due to its volume-depleting effects.

Is There a Role for Corticosteroids in the Treatment of TBI? What Is the Difference Between Vasogenic and Cytotoxic Edema?

There is no role for corticosteroids in the setting of TBI. Corticosteroids such as dexamethasone are routinely used in the treatment of cerebral edema caused by brain tumors and other inflammatory CNS processes. The mechanisms of edema in tumor and in trauma are fundamentally different. Tumors produce edema by causing inflammation and blood-brain barrier breakdown (vasogenic edema) and will respond to corticosteroids. Trauma, in contrast, causes cerebral edema (cytotoxic edema) as the result of impaired cellular metabolism causing failure of the sodium and potassium pump at the cell membrane leading to accumulation of intracellular sodium. Cytotoxic edema is not responsive to corticosteroids.

When Should a Craniotomy Be Performed for Acute EDH or SDH? What About Craniectomy?

Craniotomy (removing skull flap to evacuate hematoma) is indicated for acute subdural hematomas that are associated with a midline shift >10 mm, hematoma thickness >5 mm, or ICP >20 mmHg. Epidural hematomas >30 cc, >15 mm in thickness, or causing midline shift >5 mm should be evacuated. The bone flap is returned after the hematoma is evacuated. With a craniectomy, the scalp is closed without replacing the bone flap. This allows the brain parenchyma to swell beyond the confines of the skull. The bone flap is usually stored for possible reimplantation at a later time. A decompressive hemicraniectomy is performed if the patient's ICP cannot be managed medically. Usually as much bone as

possible is removed over the temporal fossa, or a bilateral frontal (Kjellberg) craniectomy is performed. Smaller hematomas can reasonably be monitored with serial CT scans and medically managed.

What Are the Guidelines for Repeat Imaging if a Nonoperative Management Is Planned?

Many hematomas are managed nonoperatively. Urgent follow-up CT is indicated for new neurologic signs (e.g., pupillary dilation, hemiparesis), continued emesis, worsening headache, loss of ≥ 2 points on GCS, or any signs of increased ICP. Some sources recommend a repeat head CT a few hours later to rule out a delayed hematoma (EPH, SDH, or contusions).

What Are the Criteria for Brain Death? What Conditions Must Be Ruled Out?

Brain death refers to irreversible cessation of the entire brain function including the brain stem. To perform the exam, the patient must have a GCS of 3. The patient must be eutermic ($>32.2^{\circ}\text{C}$), the PaO_2 must be greater than 90 mmHg, the SBP must be greater than 100 mmHg, and the patient cannot be sedated or paralyzed (a serum or urine drug screen may be needed). Declaration of brain death requires the absence of brainstem reflexes (corneal, gag, oculocephalic, and oculo-vestibular), no response to deep central pain, and the agreement of two physicians. If the above criteria are met, an apnea test is performed. The patient is disconnected from the ventilator and observed for respiratory effort. If there is no evidence of spontaneous respirations with a $\text{PaCO}_2 > 60$ mmHg, and the other criteria are met, the patient is declared brain dead.

What Factors Affect Prognosis of Head Injury?

Hypotension (SBP < 90 mmHg), hypoxemia, hypercarbia, elevated ICP > 20 mmHg despite hyperventilation, and increasing age are associated with worse prognosis.

Area You Can Get in Trouble

Guidelines for Head CT in Children

Children are at greater risk of malignancy from ionizing radiation from a CT scan as compared to adults. Thus, the indications for a head CT scan in a child are stricter. Indications for head CT in children include a GCS of 14 or less, suspected basilar skull fracture, a palpable skull fracture,

and altered mental status. On an individualized basis, other relative indications include loss of consciousness longer than 5 seconds; occipital, parietal, or temporal scalp hematoma; severe mechanism of injury; history of vomiting; severe headache; worsening symptoms; and child not acting normally per parent.

Summary of Essentials

History and Physical

- TBI may present with confusion, loss of consciousness, decreased level of consciousness, and amnesia.
- GCS, cranial nerve exam, and sensory and motor exam.
 - GCS of 8 or less = severe TBI
- Signs of basilar skull fracture.
 - Raccoon eyes (periorbital ecchymoses) and Battle's sign (postauricular ecchymoses)
- Intracranial hypertension.
 - Hypertension, bradycardia, and respiratory irregularity (Cushing's triad)
 - Signs of uncal herniation: blown pupil and contralateral hemiparesis

Pathophysiology

- Primary injury: occurs at the time of trauma from deformative and concussive forces and includes laceration, hemorrhage, and fracture
- Secondary injury: brain's response to injury and includes cellular ischemic injury, edema, inflammation, and disruption of blood flow
- Types of brain injury:
 - Epidural hematoma: laceration of the middle meningeal artery (most common source)
 - Subdural hematoma: rupture of the bridging veins
 - Diffuse axonal injury: stretching of axons between gray and white matter
 - Concussion: disruption of inflow and outflow tracts from reticular activating system
 - Contusion: hemorrhage within the brain parenchyma
 - Subarachnoid hemorrhage: accumulation of blood in subarachnoid space

Initial Management

- Start with ABCs.
- Intubate if severe TBI (GCS ≤ 8).
 - Protect the patient's airway.
 - Facilitate ICP management.
- STAT non-contrast head CT.
- Coagulopathy should be sought and corrected.
- ICP monitoring for select patients with moderate to severe TBI.

- An ICP >20 mmHg should be treated aggressively.
 - Elevate the head of a bed.
 - Intubate and paralyze.
 - Mild hyperventilation (avoid prolonged hyperventilation).
 - Mannitol.
 - Hypertonic saline.
 - Control pyrexia/therapeutic hypothermia.
 - Barbiturate coma.
 - Subsequent management.
- Craniotomy with hematoma evacuation.
 - Epidural hematomas >30 ml in volume or causing >5 mm of midline shift
 - Acute subdural hematomas >10 mm in thickness or causing >5 mm or shift
 - Decompressive craniectomy
 - Persistent severe intracranial hypertension despite medical management
- Criteria for brain death.
 - GCS of 3 while not hypoxic, normotensive, and eutermic, not on sedatives or paralytics
 - No cranial nerve reflexes
 - No respiratory effort observed during an apnea test

Suggested Reading

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Question Set: Neurosurgery

Questions

1. A 50-year-old woman arrives to the emergency department after she was witnessed having two generalized tonic-clonic seizures over 15 minutes without recovering consciousness between episodes. Her seizures are resolved by the time she gets to the hospital. She had a toe removed for a skin tumor 10 years ago but does not remember any details. Review of systems reveals a loss of nearly 15 lb. over the last 2 months. She has no other complaints. CT scan of the head reveals a solitary mass in the gray-white junction of the left temporal lobe with some surrounding edema but no calcifications. After further imaging and work-up are done, no other lesions are identified. Which of the following most likely represents the mass?
- (A) Type IV astrocytoma
 - (B) Metastasis
 - (C) Oligodendroglioma
 - (D) Meningioma
 - (E) Ependymoma
2. A 29-year-old male with no past medical history presents to the emergency department with the worst headache of his life. He was watching television when the headache started and is unlike any headache he has experienced before. It is located near the back of his head. He reports that his father had a kidney transplant at a young age. He is managed appropriately for his acute condition. His recovery is complicated by progressive lethargy, agitation, and eventual coma. Which of the following would most likely explain this complication?
- (A) Nephrogenic diabetes insipidus
 - (B) Central (neurogenic) diabetes insipidus
 - (C) Poor oral intake
 - (D) Cerebral salt-wasting syndrome
 - (E) Thyroid dysfunction
3. A 31-year-old male with human immunodeficiency virus (HIV) presents with headaches and night sweats. He is poorly compliant with his medications. His headaches are severe in the morning but subside throughout the day. He has no other complaints. His last CD-4 count was 95/mm³. His temperature is 37.7°C, blood pressure is 110/76 mmHg, and pulse is 88/min. His physical exam is normal. CT scan of the head shows a ring-enhancing lesion near the right primary motor cortex. What is the best next step in management?
- (A) Radiation
 - (B) Chemotherapy and radiation
 - (C) Pyrimethamine and sulfadiazine
 - (D) Stereotactic brain biopsy
 - (E) Restart highly active antiretroviral therapy (HAART)
4. A 61-year-old man with a past medical history of opioid dependence and diabetes presents with focal back pain and right leg weakness. He does not recall any recent trauma. He reports having "back surgery" nearly 20 years ago but does not remember why. He also reports helping his friend move furniture last week. His temperature is

38.8°C, blood pressure is 104/76 mmHg, and pulse is 102/min. Physical examination is significant for focal pain on palpation of his lower lumbar spine. Laboratory examination is significant for elevated ESR. Imaging is obtained. What is the best management approach for this condition?

- (A) Nonsteroidal anti-inflammatory drug (NSAID)
- (B) High-dose IV corticosteroids
- (C) Long-term antibiotics alone
- (D) Physical therapy and education
- (E) Long-term antibiotics with surgical drainage

? 5. Which of the following is the most common brain cancer?

- (A) Lung metastasis
- (B) Glioblastoma multiforme
- (C) Colon metastasis
- (D) Breast metastasis
- (E) Astrocytoma

? 6. A 64-year-old man is brought to the emergency department by paramedics after being found confused on the street. He has bruises on his head and arms with a few that appear to be new. He has alcohol on his breath. He is awake in the emergency department but unable to follow commands or answer questions. CT scan of the head without contrast demonstrates a crescent-shaped lesion. Which of the following is most associated with this patient's condition?

- (A) Family member with polycystic kidney disease
- (B) Congenital malformation
- (C) Torn bridging veins
- (D) Injured middle meningeal artery
- (E) Temporal bone fracture

? 7. In a patient with an isolated head injury and concerns for increased intracranial pressure (ICP), which of the following would have the most potential to benefit the patient?

- (A) Hypertonic (3%) saline solution
- (B) Ventilation with permissive hypercapnia
- (C) Trendelenburg position of bed
- (D) Intermittent D-5 (dextrose) boluses
- (E) Nitroprusside drip

? 8. A 20-year-old female arrives to the emergency department after slipping and hitting her head on ice and briefly losing consciousness. In the emergency room, she vomits twice. She denies amnesia. Her temperature is 37.6°C, blood pressure is 110/80 mmHg, and pulse is 80/min. Her Glasgow Coma Scale (GCS) score is 15. Her physical exam is normal with no papilledema. What is the most appropriate next step in management?

- (A) Admit for observation and order CT scan of the head only if she develops a neurologic deficit.
- (B) Admit for observation and start corticosteroids.
- (C) Order CT scan of the head without contrast now.
- (D) Discharge home now.
- (E) Discharge home with a tapered dose of corticosteroids.

? 9. A 48-year-old woman arrives for her 6-month follow-up after undergoing breast-conserving therapy to treat stage-IIA breast cancer. Her only postoperative complication has been red patches of skin on her chest following radiation therapy. She does not complain of any pain or pruritus but does report having intense headaches in the mornings when she wakes up. Her temperature is 37.7°C, blood pressure is 110/80 mmHg, and pulse is 90/min. Her physical examination is normal. She is worried that the red patches on her chest are suggestive of something more serious. Which of the following studies would be the most appropriate next step in management?

- (A) Excisional skin biopsy
 - (B) Cerebral angiogram
 - (C) Skin punch biopsy
 - (D) Carotid duplex
 - (E) CT scan of the head
10. A 29-year-old woman arrives to the emergency department following a Jet Ski accident. She has multiple bruises on her head, torso, and legs. She did not lose consciousness. Her temperature is 37.8 °C, blood pressure is 108/78 mmHg, and pulse is 102/min. She only opens her eyes when you speak loudly to her. She is confused and screams in pain and withdraws when you palpate her left lower leg. Her imaging is pending. What is her Glasgow Coma Scale (GCS) score?
- (A) 6
 - (B) 8
 - (C) 10
 - (D) 11
 - (E) 14
11. A 22-year-old patient arrives to the emergency department after falling off his bicycle and hitting his head. He is clearly intoxicated and his speech is slurred. He denies any neck pain but is not cooperative during the exam. He is placed in a cervical spine collar. What is the optimal method for clearance of the cervical spine in this patient?
- (A) CT scan of the neck only
 - (B) MRI of the neck only
 - (C) MRI of the neck followed by a CT only if the MRI is negative
 - (D) CT scan of the neck followed by MRI only if the CT is negative
 - (E) The C-spine can be cleared using physical examination
12. A 32-year-old man presents with progressive frontal headaches. His symptoms started 2 months ago and often wake him up from his sleep. His vital signs are stable, and neurologic examination reveals no focal deficits. MRI brain imaging reveals a mass, and subsequent biopsy is consistent with a type IV astrocytoma. Which of the following is true regarding this patient's illness?
- (A) It is considered the most common primary malignant brain tumor.
 - (B) Prognosis is good since the tumor is slow growing.
 - (C) The biopsy should demonstrate psammoma bodies.
 - (D) This tumor does not cross the corpus callosum.
 - (E) Interferon beta and glatiramer acetate are used in the management of this tumor.
13. Which of the following is true regarding diffuse axonal injury (DAI)?
- (A) It is often associated with a lucid interval.
 - (B) Blurring of gray-white junctions can be found on imaging.
 - (C) It occurs following a tensile force.
 - (D) Persistent vegetative state is rare.
 - (E) Patients often have hyperdense fluid in the ventricles, sulci, and cisterns.
14. A 55-year-old female restrained driver arrives to the emergency department following a motor vehicle accident. She sustained hyperextension of the cervical spine and hit her chest on the steering wheel. Neurologic examination shows spastic paraplegia and loss of pain sensation in both upper extremities. She is able to move both her legs and can differentiate vibratory sensation and light touch in both feet. What is the most likely etiology for her acute condition?
- (A) Central cord syndrome
 - (B) Anterior spinal artery syndrome
 - (C) Brown-Sequard syndrome
 - (D) Cauda equina syndrome
 - (E) Subacute combined degeneration of the spinal cord

15. Which of the following findings would be expected in a patient presenting with a transtentorial (uncal) herniation?
- (A) Loss of gag reflex
 - (B) Diplopia on attempted lateral gaze
 - (C) Medial rectus palsy on attempted lateral gaze
 - (D) Ptosis and a “down-and-out” eye
 - (E) Paralysis of the sternocleidomastoid muscle
16. A 40-year-old female presents to her family physician with progressive weakness in both her arms for the past year. She is healthy and does not take any medications but reports being hospitalized 5 years ago for 2 days following a motor vehicle accident in which she sustained severe and sudden whiplash injury. On physical examination, she has atrophy of the intrinsic muscles of both hands and an inability to differentiate between hot and cold in bilateral upper extremities. All other sensations are intact. What is the most likely underlying etiology?
- (A) Spinal spondylosis
 - (B) Brachial plexus injury
 - (C) Syringomyelia
 - (D) Autoimmune condition
 - (E) Herniated disk

Answers

1. Answer B
A solitary brain mass in the gray-white junction with surrounding edema is most consistent with a metastatic tumor. Although the most common source would be lung cancer, the history of a toe amputation highly suggests a subungual melanoma. This may occur even in patients with a remote history of melanoma. Type IV astrocytoma (glioblastoma multiforme) is considered to be the most common *primary* malignant brain tumor in the United States (A). It can cross the corpus callosum, giving it a “butterfly” appearance. However, the most common *overall* brain tumor is from metastasis. Meningioma is the second most common primary tumor in adults. Meningioma is a benign tumor that presents as an extra-axial well-circumscribed dural-based mass that may have scattered calcifications (D). Primary tumors can also present with mass effect (seizures, headaches, focal neurologic deficits). Oligodendroglioma is a rare, slow-growing tumor often found in the frontal lobes (C). It arises from arachnoid cells and is characterized by psammoma bodies on histologic examination. Ependymoma primarily affects children and commonly occurs in the fourth ventricle leading to hydrocephalus (E). Patients have a poor prognosis.
2. Answer D
Patients with subarachnoid hemorrhage can have multiple complications after their initial presentation including rebleeding, hyperglycemia, acute hypoxia, and electrolyte abnormalities. Patients are at risk for symptomatic hyponatremia secondary to *cerebral salt-wasting syndrome*. This is thought to occur because of the inappropriate secretion of vasopressin resulting in water retention. In addition, these patients have increased levels of atrial natriuretic peptide and brain natriuretic peptide which contribute to salt wasting. Patients with hyponatremia may present with seizures, lethargy, agitation, confusion, and nausea, and if untreated, patients can eventually fall into a coma. Nephrogenic diabetes insipidus is a renal dysfunction in which the collecting ducts are unresponsive to ADH, while central diabetes insipidus is associated with decreased levels of ADH released from the posterior pituitary (A–B). Both of these conditions are associated with hypernatremia. Thyroid dysfunction can rarely lead to loss of sodium (E). However, there is no evidence to believe the presented patient has any thyroid problems.

- ✓ 3. Answer C
HIV-positive patients that present with CD-4 counts between 50 and 100 per mm³, and ring-enhancing lesions found on CT scan of the head should be suspected of having either *toxoplasmosis* or *CNS lymphoma*. These are clinically indistinguishable and occur in similar frequencies. Patients should always be started first on an empiric therapeutic trial of pyrimethamine and sulfadiazine to treat a presumed toxoplasmosis infection. If this does not resolve the patient's symptoms and/or findings (e.g., ring-enhancing lesions on CT), the next best step is to perform a stereotactic brain biopsy to confirm CNS lymphoma (D). Additionally, HIV-positive patients with CNS lymphoma almost always exhibit evidence of Epstein-Barr virus (EBV) in their cerebrospinal fluid (CSF). Although no consensus exists on treatment for HIV-related CNS lymphoma, few studies have looked at treatment with radiation therapy or chemotherapy and have reported only modest gains (A–B). Restarting HAART in a patient suspected of having toxoplasmosis or CNS lymphoma increases the risk of developing immune reconstitution inflammatory syndrome (IRIS) (E).
- ✓ 4. Answer E
This patient is most likely presenting with an *epidural abscess*. Patients with previous spinal surgeries (even if remote) or a history of IV drug abuse are at higher risk. The clinical triad of epidural abscesses includes focal back pain (or headache, if abscess is located intracranial), abnormal inflammatory parameters (fever, leukocytosis, elevated ESR), and neurologic deficits (e.g., right leg weakness). MRI is the imaging modality of choice to confirm the diagnosis. Patients should be started on long-term IV antibiotics and undergo surgical drainage of the abscess. NSAIDs, physical therapy, and education would be appropriate recommendations for patients with lumbar strain (A, C–D). These patients would not be expected to have fevers or focal neurologic deficits. Current guidelines do not recommend corticosteroids after acute spinal cord injury (B).
- ✓ 5. Answer A
Malignant brain tumors are more commonly metastatic than primary (B, E). An estimated 24–45% of all patients with cancer have metastatic lesions to the CNS. Nearly half of all brain metastasis are attributed to lung cancer. The second most common cancer to metastasize to the brain is breast (15%), followed by genitourinary (11%), melanoma (9%), and head and neck cancers (6%) (D). Prostate and colon cancers do not commonly metastasize to the brain (C).
- ✓ 6. Answer C
This patient's history and CT findings are most consistent with a subdural hematoma which is caused by torn bridging veins. Patients will experience progressive neurologic deficits which if left untreated can be fatal. CT scan of the head will demonstrate a crescent-shaped lesion that may extend across the entire hemisphere. This typically occurs in older or alcoholic patients with recent head trauma, often due to a fall. Elderly patients are at increased risk due to age-related cerebral atrophy which can exert tension on the bridging veins. A family member with polycystic kidney disease is often seen in patients with subarachnoid hemorrhage due to the disease's association with berry aneurysms in the circle of Willis that are prone to rupture (A). Cerebral arteriovenous malformations can spontaneously bleed and result in a sudden intense headache and/or loss of consciousness (B). A temporal bone fracture and subsequent injury to the middle meningeal artery can result in an epidural hematoma (D–E). This classically presents with a loss of consciousness in patients with head trauma, followed by a lucid interval and then a loss of consciousness again. The hematoma is lenticular (lens shaped) or convex in shape.
- ✓ 7. Answer A
Patients with increased ICP will benefit with therapy aimed at decreasing ICP. Hyper-tonic (3%) saline solution will decrease cerebral edema by acting as an osmotic force, drawing fluid out of the tissues and into the blood and thus decrease ICP. Fluids that

contain hypotonic saline (such as dextrose 5% water) would have a deleterious effect (D). Mild hyperventilation to create *hypocapnia* is also beneficial as it induces mild vasoconstriction (CO_2 is the most potent cerebral vasodilator). Excessive hyperventilation can be deleterious as it will decrease overall perfusion. Ventilation with permissive hypercapnia is a technique used in ARDS that helps prevent barotrauma (B). However, hypercapnia (high CO_2) would lead to cerebral vasodilation and worsen ICP. Patients with head injury should be placed with the head 30 degrees elevated. Trendelenburg position will increase ICP by using gravity to increase cerebral blood flow (C). Hyperglycemia (injured brain metabolizes glucose, leading to an increase in cerebral lactate with subsequent acidosis) and nitroprusside drip (vasodilation) have also been associated with increased ICP (E).

✓ 8. Answer C

Numerous guidelines exist for when to perform a non-contrast CT in the setting of head trauma. The Canadian guidelines state that a head CT is indicated following minor head trauma and more than one episode of emesis, GCS <15 at 2 hours after injury, evidence of basilar skull fracture (Battle's sign, raccoon eyes), focal neurologic deficit, age >65 , dangerous mechanism of injury (e.g., ejected out of car), and suspected open or depressed skull fracture. Although she has a normal GCS, since she has vomited twice, a CT scan is indicated (A). Discharging the patient would be inappropriate because she meets the criteria for getting a head CT without contrast (D–E). A patient with a minor, isolated head injury and a negative CT could be safely discharged with instructions given to the patient and/or family/caregiver to look for signs of increased intracranial pressure (e.g., lethargy, vomiting, intense headaches, deficits in short-term memory, seizures, or focal neurologic deficits). Patients with these signs should return to the hospital immediately. Administration of corticosteroids is not indicated in patients with head injury (B).

✓ 9. Answer E

Any postoperative breast cancer patient with a severe headache should be evaluated for metastasis to the brain with a CT scan of the head. Postoperative radiation therapy is offered in conjunction with breast-conserving therapy (e.g., lumpectomy) to appropriate patients. Complications of radiation therapy include pneumonitis, ulceration, sarcoma, contralateral breast cancer, and red patches of skin or “radiation burns.” Skin biopsy is not needed to confirm this (A, C). These can be severe and very painful or, in this patient's case, can only be a cosmetic burden. Cerebral angiogram does not typically help in the evaluation for brain metastasis (B). Carotid disease does not typically present with headaches, so duplex scan would not be indicated (D).

✓ 10. Answer D

Once the ABCs have been addressed in a patient presenting with traumatic brain injury, one can assess a patient's level of consciousness by using the GCS as part of the primary neurologic survey. GCS is composed of three components: eye opening, verbal response, and motor response. The sum total of the three components is the GCS score, which ranges from 3 to 15. This patient has an eye score of 3 (open eyes to voice), verbal score of 4 (confused speech), and a motor score of 4 (withdraws to pain). Thus, her GCS is 11 and classified as a moderate head injury (A–C, E).

✓ 11. Answer D

Missing cervical spine injuries can have catastrophic consequences for patients. The risk of neurologic sequelae is ten times higher in patients with missed cervical injuries during initial screening versus those with injuries identified early on. CT imaging alone may be sufficient to detect all clinically meaningful injuries in patients with normal mentation (A). However, obtunded or unexamined patients may have higher rates of occult ligamentous injuries with this modality alone. Obtunded patients with a negative CT scan of the neck should be further evaluated with an MRI of the neck to optimally clear them of any cervical spine injury. CT scan of the neck should always be

done first in all patients being cleared from cervical spine injury, regardless of mentation (B–C). The C-spine can sometimes be cleared using physical examination (without imaging) (E). However, this is only true for patients that do not have any of the NEXUS criteria: neurologic deficit, spinal tenderness, altered mental status, and intoxicated or a distracting injury.

✓ 12. Answer A

Glioblastoma multiforme is a type IV astrocytoma and considered to be the most common primary malignant brain tumor in the United States. This tumor has a grave prognosis with life expectancy estimated to be <1 year from the time of diagnosis (B). On gross appearance, it can cross the corpus callosum (butterfly glioma) (D). On histologic appearance, it will stain with GFAP. Psammoma bodies are spindle cells concentrically arranged in a whorled pattern and are characteristic of a meningioma (C). Interferon beta and glatiramer acetate have been shown to decrease the frequency of future attacks in patients with multiple sclerosis (E).

✓ 13. Answer B

Patients with DAI following rapid deceleration trauma typically suffer instantaneous loss of consciousness followed by a persistent vegetative state if the DAI is severe (D). Prognosis is very poor, although some may regain some level of function. It occurs as a result of shearing forces (C). A CT scan of the head will show numerous minute punctate hemorrhages with blurring of gray-white junctions. A lucid interval is often associated with an epidural hematoma (A). Hyperdense fluid in the ventricles, sulci, and cisterns would be suggestive of a subarachnoid hemorrhage (E).

✓ 14. Answer A

This patient has central cord syndrome which classically occurs following hyperextension of the cervical spine but may also result from hyperflexion. The lateral corticospinal fasciculus is home to the motor tracts of the lower extremities and is often spared in central cord syndrome. The medial aspect hosts the motor tracts for the upper extremities and is disproportionately affected, often with profound hand weakness. Most patients regain functional recovery in a predictable fashion starting first with the lower extremities (if affected), then bladder/bowel function, and finally the upper extremities. Anterior spinal artery syndrome results from a compressed anterior spinal artery (B). This presents with bilateral loss of motor, pain, and temperature below the lesion with partial sensory sparing (e.g., proprioception, vibration) since the posterior dorsal columns remain viable. Brown-Sequard syndrome presents with ipsilateral motor weakness with associated upper motor neuron signs (spasticity, hyperreflexia, clonus, and positive Babinski sign) and touch/proprioception loss below the level of the injury, also contralateral loss of pain and temperature sensation beginning one or two dermatome levels below the level of the injury (C). Cauda equina syndrome may occur in a traumatic setting following compression of the lumbar nerve roots by a spinal fracture (D). Patients will present with perineal sensory deficit (saddle anesthesia), bowel/bladder incontinence, and pain/weakness in the lower extremities. Subacute combined degeneration of the spinal cord is the term used to describe the neurologic deficits (e.g., peripheral sensory deficits, loss of deep tendon reflexes) seen in patients with vitamin B12 deficiency (E).

✓ 15. Answer D

The uncus is a part of the medial temporal lobe and can herniate through the tentorium and compress the midbrain and brainstem during significant brain swelling. This will present with features that can be explained by local compression of nearby structures by the herniated uncus (e.g., mydriasis or “blown pupil,” ipsilateral ptosis, and “down-and-out” eye). These occur due to the compression of the parasympathetic fibers of the oculomotor nerve (cranial nerve III) by the uncus. Loss of gag reflex would be expected in patients with an injured glossopharyngeal nerve (cranial nerve IX) (A). This can occur in a patient with a posterior fossa tumor. Diplopia on attempted lateral

gaze is expected in patients with injury to the abducens nerve (cranial nerve VI), as in those patients with cavernous sinus malignancy (B). Medial rectus palsy on attempted lateral gaze is commonly seen in patients with multiple sclerosis that have medial longitudinal fasciculus (MLF) syndrome (C). Paralysis of the sternocleidomastoid muscle would be expected in patients with a spinal accessory nerve (cranial nerve XI) injury.

✓ 16. Answer C

This patient's arm weakness and inability to differentiate between hot and cold in the bilateral upper extremities are most likely due to *syringomyelia*, which is the presence of a cystic structure in the central cervical spinal cord. This most commonly occurs from congenital conditions (e.g., Arnold Chiari malformations) but may also occur months or years after a cervical spinal injury, such as whiplash (e.g., sudden distortion of the neck associated with extension). Trauma-induced syringomyelia typically involves the cervical spinal cord and results from impaired CSF drainage in the central canal of the spinal cord which may lead to a fluid-filled cavity that compresses the surrounding spinal cord. Patients will present with weakness and decreased pain and temperature sensation in bilateral upper extremities with no other sensory deficits. Spinal spondylosis occurs as a result of degenerative joint disease (e.g., osteoarthritis) and presents with radiculopathy secondary to affected nerve roots. Trauma-induced brachial plexus injuries are more likely to occur immediately following the traumatic incident and will not present with an inability to differentiate between hot and cold in the upper extremities (B). An autoimmune condition, such as multiple sclerosis, will more than likely have two lesions and present in a relapsing-remitting course (D). A herniated disk is likely but will present with radiculopathy in the affected nerve roots (E). Decreased sensation to hot and cold would not be expected.

Orthopedic

Kevin W. Rolfe

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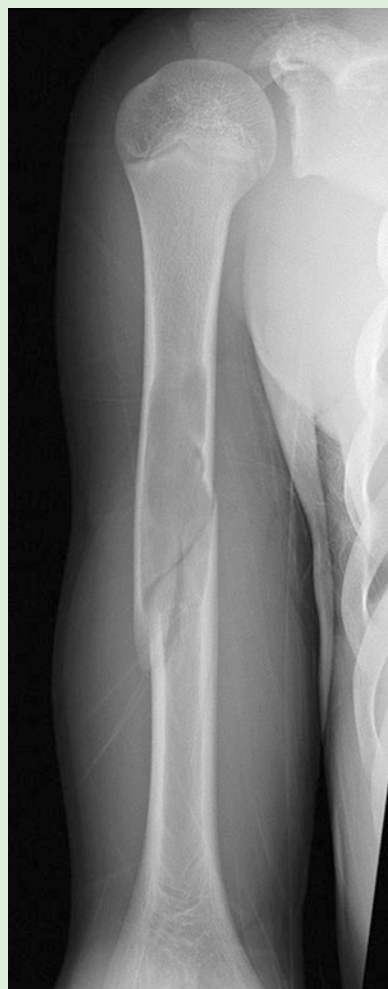
Multiple Extremity Injuries After Motorcycle Accident

Areg Grigorian, C. Max Hoshino, Spencer Albertson, and Kevin W. Rolfe

Case Study

A 35-year-old male is involved in a motor vehicle accident (MCA) and is brought in by paramedics complaining of severe pain in his right leg and arm. In the emergency department, the patient is awake and alert. He has an obvious deformity of his right mid-humerus. There are no open wounds in the arm. He has a noticeable wrist-drop on the right and is unable to dorsiflex the wrist or extend the metacarpophalangeal joints. Radial pulse on the right is 2+. There is a 2 cm laceration over his mid-shin, with visible bone exposed. Distal motor and sensory function in his right leg are intact, and pedal pulses are 2+. There is no tenderness or deformity in his left thigh or left lower leg. He also has tenderness to palpation of his right clavicle and on auscultation; a faint bruit is heard underneath the right clavicle. X-ray imaging confirms a right clavicle fracture, right mid-shaft humerus fracture (■ Fig. 30.1), a right femur fracture, and a right tibia and fibula fracture. X-rays of the left knee are negative.

■ **Fig. 30.1** Right mid-shaft humerus fracture. (From Jordanov MI. The “rising bubble” sign: a new aid in the diagnosis of unicameral bone cysts. *Skeletal Radiol.* 2009;38:597. ► <https://doi.org/10.1007/s00256-009-0685-y>. Reprinted with permission from Springer Nature)



Diagnosis

What Is the Most Likely Diagnosis?

Given the vignette and radiographic findings, the diagnosis is straightforward. This is a polytrauma patient with multiple extremity fractures including a right clavicle fracture, right closed humerus fracture with a nerve deficit, a closed right femur fracture, an open right tibia fracture, and possibly a left knee injury.

History and Physical

What Should Be Assessed During Extremity Evaluation of a Trauma Patient?

After the primary survey is completed and all life-threatening injuries are addressed, the extremities should be evaluated to assess the four functional components (nerves, blood vessels, bones, and soft tissues). Injury to three of these four elements constitutes a “mangled extremity.”

What Is an Open Fracture?

Open fractures are those in which the fracture communicates with the outer environment due to disruption of the intervening soft tissue and skin. Because of the open communication, there exists a higher risk for osteomyelitis, and infection of any hardware placed for fixing the fracture. Bone healing is also slowed in open fractures and more often results in nonhealing, known as a nonunion.

What Is the Likely Etiology of the Neurologic Deficit in His Right Arm?

The most likely etiology of the patient’s neurologic deficit is stretch or entrapment of the radial nerve due to the humeral shaft fracture. The radial nerve descends down the medial aspect of the humerus until a third of the way down, where it dives more posteriorly. At this level, the radial nerve runs in the spiral groove and remains in contact with the posterior surface of the humerus. Consequently, radial nerve injury is more common with middle and distal third humerus frac-

tures where it can be stretched from bony disconnection or become entrapped between bone ends at the fracture site. The radial nerve gives off the branches that innervate the triceps in the axilla proximal to the lesion, so triceps muscle function remains intact. Patients will experience distal loss of function including wrist-drop (weakness in extension), loss of metacarpophalangeal (MP) joint extension, and sensory loss over the dorsum of the hand.

Watch Out

Finger extension at the interphalangeal (IP) joints can still be accomplished by the intrinsic muscles controlled by the ulnar nerve (interossei and ulnar two lumbricals) and median nerve (radial two lumbricals).

What Is the Significance of Hearing a Bruit on Auscultation of the Right Clavicle?

This is concerning for an underlying vascular injury, particularly of the subclavian artery. Trauma to the clavicle can lead to pseudoaneurysm, arteriovenous fistula, and dissection of the subclavian artery. This needs to be further evaluated with a CT angiogram.

How Does Fat Embolism Syndrome Present?

Fat embolism syndrome occurs in up to 15% of polytrauma patients, particularly in association with fractures of marrow-containing bone (e.g., femur, pelvis). It typically presents between 24 and 72 hours following the trauma. The classic triad consists of respiratory symptoms, neurological changes, and a reddish-brown petechial rash. Respiratory findings such as hypoxemia, dyspnea, and tachypnea are the earliest manifestations, followed by neurologic abnormalities such as confusion, drowsiness or altered level of consciousness, and, in severe cases, seizure or paralysis. Lastly, the classic petechial rash develops, but in only 50–60% of cases. The petechial rash results from extravasation of erythrocytes secondary to the occlusion of dermal capillaries by fat emboli. The rash, in the proper clinical context, is pathognomonic for fat embolism syndrome.

What Is a Dangerous Sequela for a Tibia Fracture (or Forearm Fracture)?

Compartment syndrome. Don't forget the 6 Ps: pain out of proportion to injury with gentle passive stretch of the involved muscles, pressure (swollen and tense compartments), paresthesia, pulselessness (rare, very late sign), poikilothermia, and paralysis. This is a surgical emergency and requires emergent fasciotomy.

What Concomitant Fracture Is Important to Consider in All Femur Fractures?

A concomitant femoral neck fracture. A missed femoral neck fracture may lead to avascular necrosis (AVN) if not treated. AVN is largely irreversible and leads to end-stage dysfunction of the hip joint.

Watch Out

Femoral neck fracture is common in elderly, debilitated patients after a fall. Although this is best treated with urgent surgical intervention to prevent avascular necrosis, repair can be delayed for up to 3 days while the patient is medically stabilized and more urgent matters are addressed (e.g., atrial fibrillation, syncope).

Pathophysiology

What are Seddon's Three Basic Categories of Nerve Injury?

Table 30.1

Type	Features
<i>Neuropraxia</i>	Minimal injury (myelin), but not axon or nerve sheath. Temporary nerve conduction block, loss of motor and sensory function, but not autonomic. Full recovery expected, hours to months
<i>Axonotmesis</i>	Myelin plus axon disrupted, nerve sheath intact. Wallerian degeneration with motor sensory and autonomic paralysis. Recovery often incomplete, weeks to months, axon sprouts within nerve sheath
<i>Neurotmesis</i>	Myelin, axon, and nerve sheath also damaged. Recovery variable and incomplete at best, usually requires surgery or results in permanent paralysis

How Fast Does an Injured Axon Regenerate?

Approximately 1 mm per day, though factors like age and nutritional status may affect the rate.

Does Wallerian Degeneration Occur with Neurapraxia?

Not with neuropraxia. It does for axonotmesis and neurotmesis.

What Are the Three Layers of the Nerve Sheath?

Endoneurium, perineurium, and epineurium. Sunderland has further divided neurotmesis into three grades depending

on whether the endoneurium alone is affected, the endoneurium and the perineurium are both affected, or all three layers including the epineurium (i.e., complete transection or avulsion) are affected.

What Are the Classic Nerve Injuries Associated with Fractures?

Table 30.2

	Fracture	Classic nerve injured	Symptoms
Upper extremity	Humeral head/proximal humerus	Axillary	Impaired arm abduction
	Mid-shaft of the humerus	Radial	Impaired extension of elbow, wrist-drop
	Supracondylar (humerus)	Anterior interosseous nerve (branch of median)	Impaired handgrip
	Distal radius	Median	Impaired thumb opposition
Lower extremity	Hip fracture dislocation	Sciatic (peroneal division)	Impaired knee flexion
	Fibular head	Common peroneal nerve	Foot drop, impaired eversion/dorsiflexion

What Is the Presumed Pathophysiology of Fat Embolism Syndrome?

Embolization of fat and marrow from the fracture (or from surgical intramedullary rodding) into the bloodstream. There are both mechanical and metabolic theories as to how this embolization occurs after injury.

What Artery Is Most at Risk with a Supracondylar Humerus Fracture?

The brachial artery can be injured with this type of fracture (more common in children). Make sure to assess distal radial and ulnar pulses. In rare cases, compartment syndrome can develop and if left untreated can result in *Volkman's contracture*.

Workup

What Is the Extent of Imaging Recommended with All Long Bone Fractures?

The joint above and below any long bone fracture must always be evaluated radiographically.

What Is a Floating Knee?

This is a term for the knee when ipsilateral femur and tibia fractures are present. A floating knee tends to flail or float between bony disconnections above and below the injury.

Management

How Are Open Fractures Graded?

The Gustilo-Anderson grading system (Table 30.3) is used to grade open fractures. An increased grade correlates with a higher risk of *infection*, nonunion, and amputation. All open fractures should receive antibiotics.

What Is the Most Important Determinant of Severity for Fractures?

The energy imparted to the limb is the most important consideration. The greater the force, the higher the likelihood of a large associated soft tissue injury. For open fractures, any segmental or severely comminuted fracture should be at least a grade IIIA even if the wound is small. In some cases, a limb may have no open wounds but may be at significant risk for amputation due to significant crush or high-energy injury.

Table 30.3 Gustilo-Anderson grading system

Grade	Characteristics	Antibiotic coverage/duration
I	Wound less than 1 cm with minimal contamination or soft tissue damage	Gram-positive with first generation cephalosporin (e.g., cefazolin) for 24 hours
II	Wound 1–10 cm without extensive soft tissue damage, flaps, or avulsions	Gram-positive with first generation cephalosporin (e.g., cefazolin) for 24 hours
IIIA	Wound greater than 10 cm or high energy, but with adequate soft tissue coverage	Gram-positive and Gram-negative (e.g., cefazolin and gentamicin) for 72 hours
IIIB	IIIA with significant soft tissue injury requiring a flap or free tissue transfer	Gram-positive and Gram-negative (e.g., cefazolin and gentamicin) for 72 hours
IIIC	IIIA with vascular injury that requires a vascular repair	Gram-positive and Gram-negative (e.g., cefazolin and gentamicin) for 72 hours

What Antibiotics Are Indicated for Open Fractures in Farm Accidents or Soil-Contaminated Wounds?

Penicillin or its equivalent is *added* to cover anaerobes, especially *Clostridium perfringens*. Gas gangrene has led to many amputations in the past.

What Else Should Be Considered for Wounds Contaminated with Dirt and Soil?

Tetanus immune globulin (TIG) or tetanus toxoid (TT) administration depending on vaccine history and level of contamination (Table 30.4). Wounds at the highest risk for *Clostridium tetani* infection include those containing foreign bodies and/or necrotic tissue.

What Are the Principles of Surgical Management of an Open Fracture? What Is the Optimal Timing?

Open fractures should be taken to the operating room as soon as the patient is medically stable for surgical irrigation and debridement (Grade IIIC injuries are a surgical emergency), ideally within 6 hours, but starting antibiotics early is the most important step in management. All devitalized skin, tissue, and bone should be excised.

Table 30.4 *Clostridium tetani* infection

History of TT vaccination	Clean wounds	Dirty wounds
<3 doses	All should receive TT	All should receive both TT and TIG
≥3 doses	Should receive TT only if the last dose was more than 10 years ago	Should receive TT only if last dose was more than 5 years ago

How Are Skin Wounds Closed?

Grade I, II, and IIIA injuries typically receive primary closure, though some IIIA injuries may require multiple debridements before secondary closure due to significant contamination or inability to ascertain tissue viability at first look.

Why Is It Important to Have Early Stabilization of Open Fractures?

Restoring length, alignment, and rotation helps protect the soft tissues around the injury and prevent further damage secondary to mobile fracture fragments. Restoration of length also helps reduce dead space which decreases rates of infection. Patients that receive earlier stabilization also have quicker recovery.

Which Should Be Repaired First in a Patient with Concurrent Bone Fracture and Associated Vascular Injury with a Hard Sign (e.g., No Distal Pulse)?

These patients require a coordinated effort between the trauma, orthopedic, and vascular surgery services. The accepted sequence of events should be (1) temporary vascular shunting, (2) orthopedic stabilization, and (3) definitive vascular repair. This establishes early blood flow to the extremity.

What Is the Difference Between Open and Closed Reduction?

Reduction is the process of putting displaced bones back to their normal anatomic positions. This can either be done by direct manipulation of the bone through a surgical incision (open reduction) or indirectly by external manipulation of the limb manually or with a fracture table (closed reduction).

What Is the Difference Between Internal and External Fixation? What Are the Advantages/Disadvantages?

Fixation, as the name implies, is the act of fixating or holding the bone in place with orthopedic instrumentation often referred to loosely as hardware (e.g., wires, plates, rods, screws, or pins). Internal fixation involves placement of the instrumentation entirely within the body and under the skin with no outside communication. These are typically left in place permanently. External fixation involves placement of pins or wires into the bone, but this hardware extends outside the skin and body. These are often connected to metal rods and/or rings outside the body to maintain the bone alignment. External fixators are always removed at some point due to infection risk. The type of fixation to employ (internal or external) depends on the condition of the patient, associated injuries, and type/location of the fracture.

What Are the Main Management Concerns for a Femur Fracture?

Patients with long bone fractures (e.g., femur, humerus) are at risk for fat embolism syndrome (discussed above). Femur fractures can also present with considerable blood loss since bone is highly vascular, and the thigh compartment can accommodate a large volume of blood. Patients should also be monitored for signs of hemorrhagic shock.

What Single Type of Orthopedic Fracture is at the Greatest Risk for Hemorrhagic Shock?

Pelvic fractures. Some are benign and cause minimal blood loss, while some are highly unstable and may require a massive blood transfusion protocol due to the high pelvic volume into which blood may accumulate.

What Is the Optimal Timing of Femur Fracture Repair? What Is the Main Risk if Repair Is Delayed? What Are the Main Options in Repair?

The American College of Surgeons recommends definitive surgical management of femur fractures within 2–12 hours of injury, provided that they are hemodynamically stable and medically stable. Patients who undergo surgical repair within 24 hours have decreased rates of mortality and morbidity. Definitive management is most often accomplished



Fig. 30.2 Intramedullary nail for femoral fracture (From Li X, et al. Pseudoaneurysm of the profunda femoris artery following a long anterograde intramedullary nail for an unstable intertrochanteric hip fracture: a case report and review of the literature. *Eur J Orthop Surg Traumatol.* 2011;21:293. ► <https://doi.org/10.1007/s00590-010-0700-y>. Reprinted with permission from Springer Nature)

with *intramedullary nailing* in the adult, though external fixation is sometimes used temporarily in unstable patients as this can be performed more quickly and easily and does not involve reaming the canal which can increase the risk of developing fat embolism syndrome (■ Fig. 30.2).

Do All Femur Fractures Require Fixation?

No, children less than 3–5 years are usually managed with spica casting and do not carry the same risk of morbidity and mortality associated with femur fractures as in adults.

What Should Be Considered in a Child Who Is Not Yet Walking and Presents With a Femur Fracture?

Child abuse. In some cases, these children are found to have fragile bones as in osteogenesis imperfecta.

What Is the Management for Fat Embolism Syndrome?

Management of fat embolism syndrome consists of supportive care including ventilatory support with high positive end expiratory pressure (PEEP).

What Is the Most Important Factor to Prevent Fat Embolism Syndrome Before It Occurs in a Polytrauma Patient?

Early stabilization of long bone fractures within the first 24 hours.

What Is the Management for a Clavicle Fracture?

Most clavicle fractures involve the middle and proximal third, which can be managed with a sling/brace, rest, and ice. Significantly displaced fractures that cause tenting of the skin can lead to pressure necrosis and may require open reduction with internal fixation.

Postoperative

What Are the Important Risks Associated with Fracture Treatment?

Infection, iatrogenic nerve or vessel injury, nonunion (failure to heal), malunion (healing in an improper position or alignment), or instrumentation failure.

Area of Controversy

Limb Salvage or Amputation

When the lower limb has been severely damaged (known as a mangled extremity), it is often difficult to determine whether to attempt limb salvage or simply amputate. Factors favoring primary amputation include a hemodynamically unstable patient, prolonged ischemia, and the severity of the force (which will more often lead to a combination of severe soft tissue, bone loss, arterial, and nerve injury). There is a scoring system known as the Mangled Extremity Severity Score to help clinicians decide the best course of management. Limb salvage is associated with prolonged hospitalization, multiple surgeries, and higher initial cost which may take a psychological toll on the patient. Patients, however, prefer limb preservation in most cases. Amputation is associated with faster initial return to function but may have similar or higher long-term cost due to prosthetic limb needs. Of significant note,

the old teaching that any plantar insensate foot should prompt amputation of a mangled limb is no longer a singular criterion in the decision to amputate or attempt salvage.

Areas Where You Can Get in Trouble

Missing Other Fractures

A joint above and below any fracture must always be assessed radiographically. This is one of the greatest sources of missed injury aside from incomplete clinical secondary surveys for additional injury. In some cases, a missed foot injury that was not treated properly at the outset will plague the patient more than the dangerous femur fracture which has subsequently healed without sequelae. The most commonly missed fractures in trauma patients are of the hand and foot.

Failure to Recognize a Compartment or Impending Compartment Syndrome

Multiple clinical assessments should be made to guard against missing this entity, which is a surgical emergency. Direct compartment pressure measurements can help, but the decision to proceed with a fasciotomy can be made with just a clinical exam. The lower limb and forearm are most at risk, especially with crush injuries. The hand and foot are the second most common.

Watch Out

In addition to compartment syndrome, beware of rhabdomyolysis and subsequent kidney failure in patients with crush injuries.

Failure to Recognize a Neurologic Deficit

A radial nerve deficit is important to determine as it may need separate treatment or dictate treatment options. Also, if a preoperative nerve deficit was missed and not documented, then a postoperative nerve deficit may be attributed by the patient to an operative complication and/or lead to medicolegal issues.

Summary of Essentials

History and Physical

- Inquire as to the mechanism of injury.
- Fat embolism syndrome (24–72 hours after injury): respiratory symptoms, neurological changes, and reddish-brown petechial rash.
- Four functional components of extremity exam (nerves, vessels, bones, and soft tissues).

Pathophysiology

- Fat embolism syndrome:
 - Embolization of fat and marrow content from marrow-containing bones, especially the femur, mostly affects the brain and lungs
- Three nerve injuries: neuropraxia, axonotmesis, and neurotmesis.
- Humeral shaft fractures associated with radial nerve injury and wrist-drop.
- Open fracture communicates with environment due to disruption of soft tissue and skin and requires special treatment due to infection risk.

Diagnosis

- Diagnosis usually straightforward with fractures after acute trauma.
- Perform a thorough secondary survey to avoid missing additional fractures.
- Radiographs must include the joint above and below all fractures seen on x-ray.
- Any soft tissue wounds in conjunction with a fracture constitute an open fracture.
- In patients with femoral fractures, always evaluate for femoral neck fracture.

Management

Open Fracture

- All open fractures should receive antibiotic coverage: first-generation cephalosporin +/-aminoglycoside.

- Irrigation and surgical debridement.
- External fixation for immediate and temporary control if unstable patient.
- Definitive management with internal fixation.

Closed Fracture

- Managed within 2–12 hours with intramedullary nailing
- Reduces risk of fat embolism syndrome

Postoperative

- Main surgical risks include infection, nonunion, malunion, nerve or vessel injury, and amputation in some cases.

Suggested Reading

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Immediate Swelling After Trauma to the Knee

D' Ann E. Arthur, Spencer Albertson, and Kevin W. Rolfe

Case Study

A 26-year-old otherwise healthy male presents to the clinic with right knee pain after a skiing accident 3 days ago. The patient landed awkwardly after attempting a jump and experienced the immediate onset of right knee pain necessitating ski patrol to bring him down the mountain. The patient reports hearing a “popping” noise when landing. Shortly after he noticed swelling around his knee, he was still able to

bear weight on his leg. Today in clinic, the patient can ambulate with a single crutch on a slightly flexed knee without the knee buckling. On physical exam, a large effusion is present over his anterior knee. There is mild warmth and tenderness to palpation around the medial joint line. Muscle compartments in the leg are soft and pulses are 2+. Neurologic exam reveals normal motor and sensory function distal to the

knee. The patient is able but hesitant to perform active or passive knee range of motion secondary to pain. There is increased knee laxity of 1 cm when an anterior force is applied to the tibia at 30° and 90°. There is no laxity with varus or valgus stress applied to the knee. Compression and axial rotation across the knee joint while extending it from a fully flexed position produces neither pain nor a palpable or audible snap.

Diagnosis

What Is the Differential Diagnosis for Acute Knee Pain?

Table 31.1

Diagnosis	Comments
<i>Hemarthrosis, bone infarct</i>	History of hemophilia or sickle cell disease
<i>Septic arthritis</i>	Fever, erythema and warmth of knee, unwillingness to bear weight or range a knee held constantly around 30° of flexion; <i>Neisseria gonorrhoeae</i> type common in sexually active young individuals
<i>Acute osteomyelitis</i>	Fever and constitutional symptoms especially in association with immunocompromise (HIV, sickle cell, diabetes, alcoholism, chronic corticosteroid use), intravenous drug abuse, or children
<i>Neoplastic</i>	Constitutional symptoms, typically more insidious onset (except pathologic fracture through tumoral bone); acute fracture across a benign preexisting bone lesion or cyst would not be distinguishable from ordinary fracture without imaging studies
<i>Inflammatory</i>	History of rheumatoid arthritis (flare up) or crystalline arthropathy; focal tenderness over the affected area (bursitis, tendinitis)
<i>Traumatic</i>	Onset of pain at time of acute sporting or vehicular injury; fractures associated with <i>unwillingness to bear weight</i> more than ligamentous or soft-tissue injuries but may occur together; acute patellar or quadriceps tendon rupture prevents ability to actively, fully extend knee despite adequate passive motion
<i>Iatrogenic/ drugs</i>	History of recent knee injection (postinjection inflammation and/or infection)

HIV human immunodeficiency virus

Watch Out

Ligamentous injuries classically present with immediate swelling, while meniscal tears develop swelling the next day.

What Is the Most Likely Diagnosis?

In a young healthy male with sudden knee pain immediately following a skiing accident, a traumatic etiology is most likely. Since the patient can bear weight, fracture is less likely, though not entirely ruled out. Anterior knee laxity on physical exam suggests anterior cruciate ligament (ACL) disruption. Varus and valgus stability make associated medial collateral ligament (MCL) and/or lateral collateral ligament (LCL) disruptions less likely. As the patient's knee does not buckle despite a flexed knee gait during weight bearing in conjunction with no palpable tendon defects, quadriceps or patellar tendon rupture is less likely. Though commonly associated with ACL tears, a meniscal tear is less likely in the presence of a negative McMurray sign (no pain, no palpable or audible snap with a compression and axial rotation maneuver of the knee while extending it from a fully flexed position).

History and Physical Exam

What Are the Principal Components of the Knee Exam?

Table 31.2

Component	Features
<i>Gait</i>	Look for obvious gait abnormalities
<i>Observation</i>	Fully expose and compare both knees, look for atrophy, past scars, swelling, bowing, and landmarks (e.g., patella, anterior tibial tuberosity)
<i>Palpation</i>	Temperature (e.g., warmth) and effusion (e.g., patella floats and “bounces” back when pushed down)

■ Table 31.2 (Continued)

Component	Features
Range of motion	Active and then passive (e.g., clinician moves the joint), listen for crepitus
Joint line tenderness	Evaluate for medial or lateral meniscal injuries or arthritis
Neurovascular	Check distal pulses and sensation of knee and lower legs
Knee maneuvers	Lachman's test, anterior drawer, McMurray's test, and pivotal shift tests (see ■ Table 31.1)

What Is the Classic History for the Various Ligamentous Injuries in the Knee?

■ Table 31.3

Ligament	Classic history
Anterior cruciate ligament (ACL)	Posterior blow to the lateral knee
Posterior cruciate ligament (PCL)	Anterior blow to the lateral knee
Medial collateral ligament (MCL)	Lateral blow to the knee (valgus stress)
Lateral collateral ligament (LCL)	Medial blow to the knee (varus stress)

What Are the Classical Physical Exam Signs for Knee Injuries and How Are They Performed?

■ Table 31.4 describes the clinical tests used to evaluate knee pain. All are performed supine, except for the dial test which is performed with the patient prone. Side-to-side comparison is most important to determine the presence of laxity.

Watch Out

Don't confuse McMurray's sign with Murphy's sign (cessation of inspiration with right upper quadrant palpation associated with acute cholecystitis).

What Does a History of Locking or Catching Signify?

Intermittent locking or catching with range of motion of the knee most commonly signifies a mechanical blockage to motion. This is most often associated with meniscal tears,

■ Table 31.4 Knee maneuvers

Structure	Clinical finding/test	Description
Anterior cruciate ligament (ACL)	Anterior drawer or Lachman's test	Knee flexed at 90°, forward traction on the lower leg causes the tibial plateau to move forward relative to the knee suggesting a torn ACL
Posterior cruciate ligament (PCL)	Posterior drawer test or "tibial sag" on 90° flexion	Knee flexed at 90°, posterior force on the lower leg causes the tibial plateau to move posteriorly relative to the knee suggesting a torn PCL
Meniscal cartilage	McMurray's test	Extending the knee from a fully flexed position (heels on buttocks) and simultaneously applying compression and axial rotation (torsion) across the joint; positive if pain or an audible or palpable snap (more specific) along the joint line signifying meniscal tear
Lateral collateral ligament (LCL)	Varus instability	Thigh pushed on medial side in lateral direction while foot pushed on lateral side in medial direction, significant laxity suggests LCL tear
Medial collateral ligament (MCL)	Valgus instability	Thigh pushed on lateral side in medial direction while foot pushed on medial side in lateral direction, significant laxity suggests MCL tear
Posterior lateral corner (PLC)	Dial test	With the patient prone, external rotation is checked on both legs at 30° and 90° of flexion; >10° of external rotation asymmetry at 30° only is consistent with an isolated PLC injury; >10° of external rotation asymmetry at 30° and 90° is consistent with a combined PLC and PCL injury

especially tears with mobile flaps. Patients often have medial joint tenderness. Loose osteochondral bodies in the joint space can also present with locking/catching.

Why Is It Important to Perform a Careful Vascular Exam?

Injuries such as posterior knee dislocation or proximal tibia fracture can damage the popliteal artery leading to acute limb ischemia which may lead to amputation if not recognized and treated promptly. Pulses should always be assessed and ankle-brachial indices (ABIs) performed if there is any uncertainty. An ABI <0.9 indicates a high likelihood of vascular injury and warrants further workup with a CT angiogram.

Why Is It Important to Perform a Careful Neurologic Exam?

Global instability after knee dislocation, significant ligamentous disruption, or fracture can damage the major nerves or branches traversing the region. Foot drop (with “slapping” gait) and numbness of dorsum of foot, due to damage to the common peroneal nerve, are the most common neurologic deficits. Immediate stabilization of an unstable knee may be indicated to protect these structures and thus prevent further damage. Surgical exploration and nerve repair are sometimes needed.

What Is the Significance of Having Soft Muscular Compartments in the Lower Leg?

This helps rule out compartment syndrome, which is a true surgical emergency with a limited window of time for intervention (fasciotomy) before irreversible tissue death. The most sensitive clinical finding for compartment syndrome is pain with passive stretch. This can be performed by performing passive range of motion of the great toe. Don't forget the six Ps of compartment syndrome: pain (out of proportion to injury), pallor, paresthesia, pulselessness (rare and very late finding), poikilothermia, and paralysis.

What Is the Importance of Asking About Fever and Other Constitutional Symptoms Such as Fatigue, Weight Loss, Night Sweats, and Decreased Appetite?

Constitutional symptoms are associated with tumors and infection. These should be considered, even in the setting of trauma as trauma can precipitate a pathological fracture.

What Is the Importance of Asking About Previous Knee Surgery?

Patients with previous knee surgery may have hardware/prosthesis used in the repair. This can serve as a nidus for subsequent infection.

Watch Out

Patients presenting with knee infection within the first 3 months after knee surgery with hardware/prosthesis implants likely are infected with a highly virulent organism such as *Staphylococcus aureus*. Those that have a delayed onset (>6 months) with chronic pain are more likely to be infected with less-virulent organism such as a coagulase-negative *Staphylococcus epidermidis*.

What Should Be Considered in Patients with Recurrent Fractures?

Although a patient with a recurrent fracture may report minor trauma as the inciting event, recurrent fractures should raise the suspicion for infection (osteomyelitis) or neoplasms within the bone resulting in pathologic fracture. Osteosarcomas are malignancies that lay down bony osteoid material that can mimic healing fracture callus on radiographs.

What Is the Significance of Being Able to Bear Weight?

When the patient can bear substantial weight on the limb, fractures and septic arthritis are less likely.

Why Is It Important to Look for Lacerations or Wounds?

Wounds or lacerations after a trauma may signify an *open fracture* which is a surgical emergency.

Pathophysiology

What Two Basic Mechanisms Lead to ACL Injury?

Contact and noncontact pivoting injuries. Contact injuries involve a direct blow to the knee, often a lateral or hyperextension blow to the knee (e.g., with a helmet as may be seen in football). Noncontact ACL injuries are far more common. These typically occur during pivoting sports including football, basketball, and soccer and are commonly associated with awkward landings.

Is ACL Injury More Common in Men or Women?

Among active sports participants, the incidence of ACL injury is four to five times more common in women. This difference in rate is likely multifactorial including differences in anatomy (females have a smaller ACL and smaller intercondylar notch), landing mechanics (females land with greater knee valgus and extension), and muscular imbalance (females have a lower hamstring to quadriceps strength ratio). Additionally, the changes in hormones with the menstrual cycle have been shown to affect the rate of ACL rupture (in fact the highest risk of injury is in the preovulatory phase).

What Is the Terrible (aka “Unhappy”) Triad of the Knee?

A combination of MCL, ACL, and medial meniscus injuries

Watch Out

Don't confuse the terrible triad of the knee with that of the elbow (elbow dislocation with coronoid and radial head fractures).

What Is a Common Method of Injuring the Medial Meniscus?

These patients often report a twisting injury while their foot is fixed.

What Is the Distribution of Blood Supply to the Meniscus and Why Is It Important?

The menisci receive blood peripherally from outside-in to cover only the outer 25–30% of their diameter. Tears occurring in the outer “red” zone have the potential to heal and are often repaired. Inner tears in the “white zone” without a direct blood supply have little healing potential. As such, tears in the “white zone” are not repaired but surgically debrided if needed.

What Is the Significance of a “Popping” Noise on Traumatic Injury?

Although a “popping” noise can occur with meniscal injuries, it is most commonly associated with ACL rupture. High tension on the ligament immediately before the tear may cause the audible noise. Some believe that the noise occurs due to sudden collision between the bone ends of the femur and tibia.

What Injury Would You Expect from a Dashboard Knee Injury?

A dashboard knee injury occurs in a motor vehicle accident when a flexed knee hits the dashboard subjecting it to an anterior force. This mechanism is associated with posterior cruciate ligament (PCL) injury and a positive posterior drawer test.

What Is the Normal Range of Motion of the Knee?

Range of motion of the knee is tested with the patient lying supine and the hip partially flexed. Normal range is 0–5° extension to 130–140° flexion.

What Is the Significance of Being Unwilling (vs. Unable) to Range the Knee?

If the patient is unwilling to range the knee, then fracture or septic arthritis should be highly suspected. Without an acute trauma or x-rays showing fracture, septic arthritis should be considered and *arthrocentesis* (tapping the knee and sending the fluid for laboratory analysis) performed.

What Is the Significance of Being Unable to Actively or Fully Extend the Knee While the Examiner Can Do So Passively?

Inability to actively extend the knee to full extension suggests either a mechanical block to motion or a disruption of the bones or tendons involved with knee extension. If passive extension is normal, but the patient cannot actively extend the knee, then there is disruption of the extensor mechanism (either the quadriceps or patellar tendon or fracture of the patella or tibial tubercle). Note that these tendon ruptures are more common in middle-aged, “weekend warrior” athletes.

What About Pain Inferior to the Patella with an Intact Extensor Mechanism of the Knee?

“Jumper’s knee” or *patellar tendinitis* is a common entity with pain along the patellar tendon near its attachment to the patella. This occurs in patients involved in sports requiring constant jumping (e.g., basketball) or repetitive forceful knee extension (e.g., soccer). A similar tendinitis may occur along the distal quadriceps tendon.

Why Is It Important to Examine the Patella and Its Tracking?

The patella has often been called the “low back” of the knee, meaning its problems are often as difficult to treat as chronic low back pain. Patellar dislocations occur laterally and involve an increased Q-angle (■ Fig. 31.1). Flat feet and knock knees (valgus) increase the Q-angle. Additionally, females on average have a higher Q-angle than men, which makes patellar instability more common in females than males.

Workup

What Is the Next Step in the Workup of This Patient?

Radiographs of the knee are taken to evaluate for fracture, alignment or deformity, infection, and tumor.

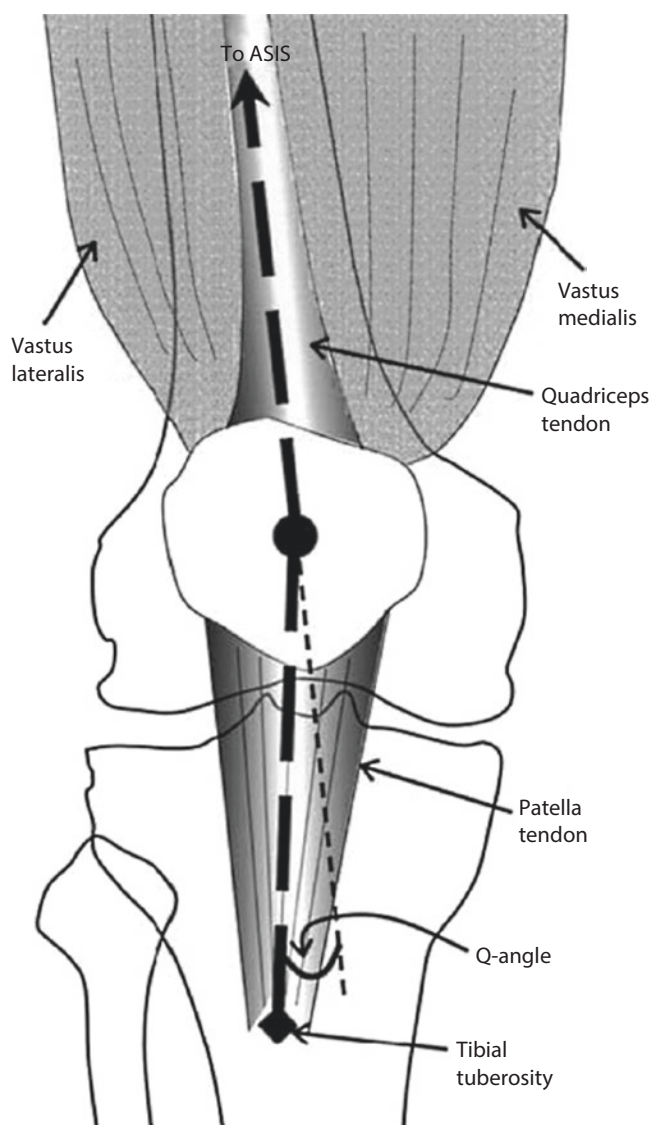


Fig. 31.1 Measurement of the Q-angle is the angle formed by a line drawn from the ASIS to the patella and a second line from the patella to the tibial tuberosity. (From Houghton KM. Review for the generalist: evaluation of anterior knee pain. *Pediatric Rheumatology Online J.* 2007;5:8. Open Access)

What Radiographic Sign Is Pathognomonic for ACL Injury?

A Segond fracture or small fleck of bone avulsed from the lateral tibial plateau is almost universally associated with ACL disruption when it is seen (Fig. 31.2).

What Is the Meaning of Patella Alta and Baja on an X-Ray?

The patella may ride high (alta) due to unopposed pull from the quadriceps in the setting of a patellar tendon rupture. Conversely, it may ride low (baja) with quadriceps rupture.



Fig. 31.2 Second fracture: lateral tibial plateau avulsion pathognomonic for ACL injury. (From Zaffagnini S, et al. Anterior cruciate ligament injuries. In: Margheritini F, Rossi R, editors. *Orthopedic sports medicine*. Milano: Springer; 2011. Reprinted with permission from Springer Nature)

What Are the Characteristic Radiographic Features of Osteoarthritis of the Knee and Why Is It Important to Consider After ACL Injury?

Radiographic changes consistent with degenerative arthritis in the knee include joint space narrowing, osteophytes (bone spurs), subchondral sclerosis, and subchondral cysts (Fig. 31.3). These changes are critical to recognize as ACL surgery is not appropriate in the setting of significant arthritis of the knee.

How Should Suspected Septic Arthritis or Crystalline Arthropathy Be Worked Up?

A hot, swollen knee without a preceding trauma should prompt knee *arthrocentesis* (needle aspiration to obtain *synovial fluid* for culture and pathology including cell counts and crystal analysis). Unwillingness to bear weight or range the knee, especially with fever, suggests a serious joint infection which requires emergent intervention. Gross purulence on aspiration is infectious until proven otherwise (although

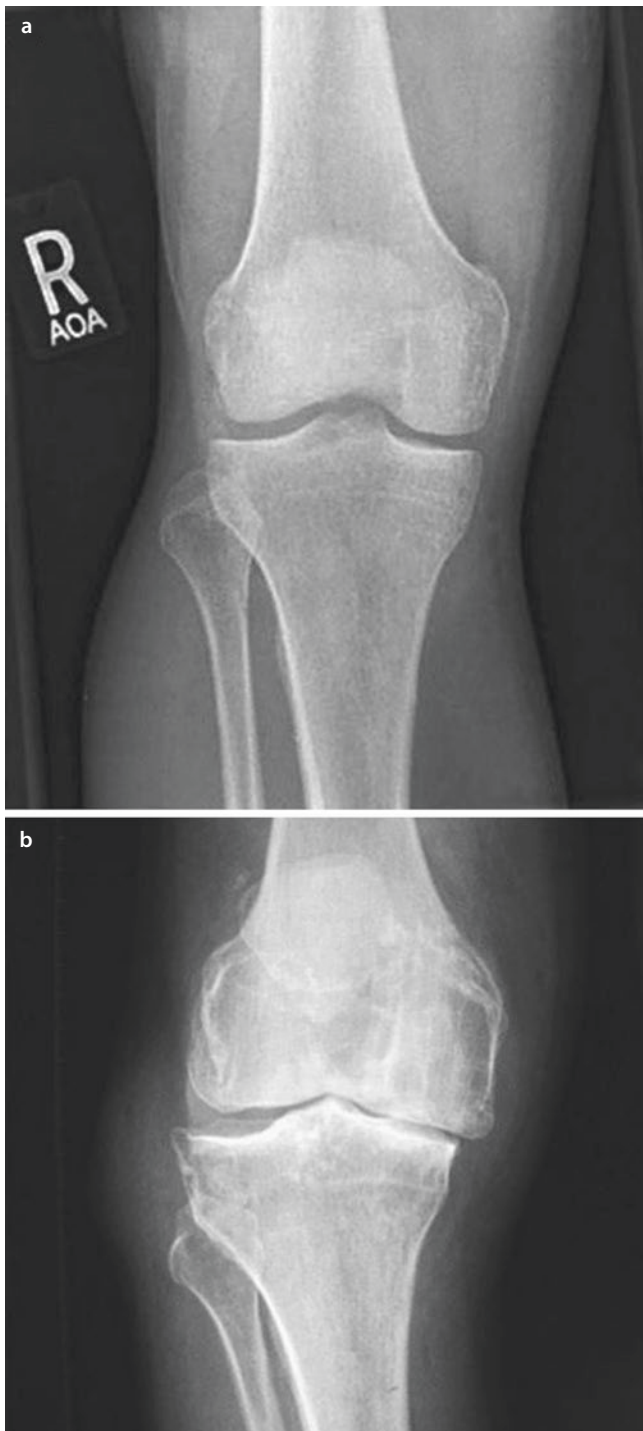


Fig. 31.3 **a** Normal radiograph of the knee. (From Abdul-Jabar HB, et al. Primary meningococcal oligoarthritis of the knee—case report and review of the literature. *Eur Orthop Traumatol.* 2011;2:149. ► <https://doi.org/10.1007/s12570-011-0078-2>. Reprinted with permission Springer Nature). **b** Arthritic knee. (From Leonard M, Murphy PG. End-stage osteoarthritis of the knee presenting with foot drop. *Eur J Orthop Surg Traumatol.* 2007;17:399. ► <https://doi.org/10.1007/s00590-007-0200-x>. Reprinted with permission from Springer Nature)

pseudogout can give this appearance as well). Pseudogout crystals are formed of calcium pyrophosphate and are rhomboid in shape and positively birefringent (purple) on crystal

analysis. Gout crystals are formed of monosodium urate and are needle shaped and negatively birefringent (yellow) on crystal analysis. White blood cell (WBC) counts in synovial fluid less than 200/ μ L are normal. Inflammatory conditions range from 200 to 50,000/ μ L, and above 50,000/ μ L is infectious. There may be diagnostic ambiguity near the overlapping ranges between disease processes.

Watch Out

Don't confuse arthrocentesis white cell count thresholds with those of cerebrospinal fluid (CSF) after lumbar puncture for meningitis, etc. Normal WBCs in CSF are up to 5/ μ L in adults and 20/ μ L in newborns, and 100–1000/ μ L is highly likely to be a serious, infectious bacterial meningitis.

What Imaging Would You Use to Confirm a Suspected ACL Injury?

MRI is the *best* technique to evaluate the integrity of the ACL. Likewise, the menisci are best evaluated with MRI.

Management

Is There a Role for Nonoperative Management of ACL Tears?

Nonoperative management of ACL tears can be considered with (a) partial tears and no instability symptoms, (b) those with complete tears with no symptoms of knee instability during low-demand sports who are willing to give up high-demand sports and (c) those who do light manual work or live sedentary lifestyles, (d) those with advanced osteoarthritis, and (e) those with significant comorbidities precluding surgery. These may be managed nonsurgically with activity modification, bracing, and physical therapy focused on strengthening the muscles which serve to dynamically stabilize the knee, especially the hamstrings. Note that acute symptomatic treatment includes the RICE formula: rest, ice, compress, and elevate.

What Are the Risks of Nonoperative Management of an ACL Injury?

The primary goal of ACL repair is to re-establish knee stability and to increase function. Nonoperative management may lead to abnormal knee motion and may increase the risk of future meniscal injury. Some studies have shown that patients that do not undergo ACL reconstruction have higher rates of eventual total knee replacement surgery than those who have ACL repair.

What Is the Management for the Patient in This Case?

A young, healthy, athletic patient without preexisting arthritis involved in a high-energy injury that, most likely, wishes to return to a high level of athletic function is an excellent surgical candidate. Surgery entails arthroscopic *reconstruction* of the ACL, not repair. Reconstruction involves use of a tendon graft placed into bone tunnels across the knee in the femur and the tibia approximating the normal position of the ACL. Attempts at repair of the native ligament do not heal due to the intra-articular location and presence of synovial fluid which inhibits local healing.

What Is the Management of a Meniscal Tear?

Most tears that are small or causing infrequent symptoms can be managed successfully with the RICE approach followed by physical therapy. Surgery is considered for patients with persistent and/or disabling symptoms and those involving large, complex tears in contact with the articular cartilage. Repairing only the meniscal tear in patients that have an associated ACL tear has been shown to have poor results without ACL reconstruction due to changes in joint biomechanics in the ACL-deficient knee. As such, repair should only be considered in the setting of concomitant ACL reconstruction. Traditional literature showed higher rates of meniscus healing with concomitant ACL repair; however current literature debates this.

Postoperative

What Are the Main Risks Associated with ACL Surgery?

Risks include postoperative infection and septic arthritis which can damage precious cartilage which has virtually no capacity to regenerate and lead to early arthritis. Additional risks include knee stiffness, local saphenous neuroma formation due to surgical incisions, and graft failure. Graft failure is much higher if a concomitant LCL disruption is missed and not treated. Poor or improper placement of the graft may also lead to ongoing instability or abnormal knee mechanics. A good postoperative rehabilitation program is crucial to a good clinical outcome.

Areas of Controversy

What Are the Different Types of ACL Grafts Used?

Graft selection for ACL reconstruction includes *autograft* harvested from the patient (bone-patellar tendon-bone or hamstring tendon) versus cadaveric *allograft*. Advantages to autograft include decreased risk of disease transmission or

immunologic reaction and faster incorporation of the graft. The cells of autograft are more viable as they are taken fresh from the patient at the time of surgery. Disadvantages to autograft include donor-site morbidity such as anterior knee pain, weakness of knee flexion or pain with hamstring graft, and longer operating times. Allograft prevents donor-site morbidity of autografts but carries a risk of disease transmission. Allografts are typically processed by freezing or irradiating to decrease immunogenicity and disease transmission, but the processing weakens the allograft and decreases cell viability and incorporation rates.

What About ACL Injuries in Adolescents Who Have Not Completed Their Growth?

Since the ACL requires reconstruction and reconstruction involves drilling bone tunnels across the proximal tibia and distal femur, there is a risk of growth plate damage (physeal arrest) with ACL surgery in this age group. As a result, both physeal sparing and transphyseal techniques have been attempted, though growth disturbance does not seem to differ between the techniques. Amount of remaining growth and risk of physeal arrest should be considered when deciding when to perform surgery on the ACL-deficient adolescent.

Areas Where You Can Get in Trouble

Failure to Recognize a Knee Dislocation or Vascular Injury

The knee should be examined fully after significant trauma. Significant instability needs to be assessed and recognized on exam as it will change the acute management. Static radiographs may not reveal a globally unstable knee after dislocation due to spontaneous reduction or positioning of the knee during the x-ray. The vascular status of the limb must be considered with pulses and ABIs.

Failure to Recognize a Septic (Infected) Knee Joint

If a septic knee is missed, the intra-articular cartilage can be completely destroyed by the bacteria. Cartilage has little to no capacity to heal, so the patient will be left with an end-stage arthritic knee joint that is painful and functions poorly.

Summary of Essentials

Diagnosis

- Acute trauma to knee with anterior knee laxity suggests ACL injury.
- If patient can bear weight, fracture is less likely.

History and Physical Exam

- Components of knee exam: gait, observation, palpation, range of motion, joint line tenderness, neurovascular, and knee maneuvers
- Knee maneuvers: anterior drawer/Lachman's, posterior drawer, McMurray's test, and varus/valgus instability
- Knee dislocations can damage vasculature creating dysvascular limb risking amputation.
- Ligament injury presents with immediate swelling; meniscal injury has delayed swelling.

Etiology/Pathophysiology

- ACL injury:
 - Contact versus noncontact (more common) pivoting injuries
 - Audible pop during an acute sports-related injury involving an awkward landing or twisting mechanism
- Unhappy triad:
 - MCL
 - ACL
 - Medial meniscus
- Q-angle in patellar dislocation

Workup

- Start with radiographs to look for fracture, alignment or deformity, infection, and tumor.
- MRI for confirmation.

Management

- Treatment made on individualized basis.
- Treatment for all patients begins with:
 - Rest
 - Ice
 - Compress
 - Elevate
- Patients begin physical therapy as soon as they are able to tolerate treatment to restore range of motion prior to surgical intervention.
- Consider nonoperative management for elderly and low-demand patients.
- Surgery for reconstruction, not repair.

Postoperative

- Infection, knee stiffness, and graft failure.
- Exhaust all conservative options before reoperating.

Suggested Reading

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Adolescent Male with Right Groin Pain and Limp

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Case Study

A 12-year-old moderately obese boy presents with right groin pain and a limp. He states that the pain is worse with walking and relieved by rest. The pain begins in his right groin and radiates to his right knee. The pain began about 1 month ago without antecedent trauma and has progressively worsened. He has no pain in any other joints

or extremities. He has no recent infections and reports no associated fevers, chills, or malaise. He participates in physical education at school but is otherwise not involved in sports. He has no recent travel or camping trips and lives in an urban area. He takes no medications. There is no family history of joint problems. On physical examination, he

is afebrile. The right lower extremity rests in a slightly externally rotated position compared to the contralateral extremity, and he resists internal rotation. There is no leg length discrepancy. Neurologic and vascular exam are normal. Erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) are within normal limits.

Diagnosis

What Is the Differential Diagnosis for Groin Pain with a Limp or Refusal to Bear Weight?

Table 32.1

Infectious	History and physical
Septic arthritis	Triad of fever, pain, and impaired range of motion; a surgical emergency
Lyme disease	<i>Ixodes</i> tick bite (<i>Borrelia burgdorferi</i> bacteria); early signs include chills, fatigue, erythema chronicum migrans (bull's-eye rash); late signs include chronic synovitis, monoarthritis or oligoarthritis, aseptic meningitis
Psoas abscess	Fever, patient holds thigh in slight hip flexion and internal rotation, passive hip extension which stretches the psoas muscle is met with significant pain; can be associated with osteomyelitis of the spine, appendicitis or other intraabdominal infections
Inflammatory	
Juvenile idiopathic arthritis	Nonmigratory arthropathy affecting one or more joints for >3 months, morning stiffness, fevers
Transient synovitis	History of a recent upper respiratory tract or other viral infections in the presence of hip pain; average age 2–5 years; most common cause of hip pain during childhood; pain is usually worse upon awakening and improves as the day progresses; often self-limiting
Mechanical	
Developmental dysplasia of the hip	In infants, seen with positive Barlow's and Ortolani's tests (provocation of hip dislocation or reduction, respectively), Galeazzi's sign (knees at unequal heights when hips/knees flexed); in toddlers, positive Trendelenburg sign; untreated will have delayed walking or abnormal gait
Legg-Calve-Perthes disease	Idiopathic osteonecrosis of femoral head; most common ages 4–8 years; gradual progressive limp, slow onset of pain, decreased range of motion

Table 32.1 (Continued)

Infectious	History and physical
Stress fracture	Insidious onset of pain with activity or repeated loading; typically, patient has no history of recent trauma; pain subsides at rest; local tenderness and swelling
Slipped capital femoral epiphysis	Obese, adolescent male aged 10–16 years old presenting with groin pain, painful limp, externally rotated hip, pain with forced internal rotation
Neoplastic	
<i>Benign</i>	
Osteoid osteoma	Continuous, deep, aching bone pain in young patient; typically, affects neck or back; unexplained, rigid, painful scoliosis
<i>Malignant</i>	
Osteosarcoma	Most common primary malignant bone tumor; age range 10–30 years but more common in adolescent males; deep bony pain that progresses to palpable bony mass; typically affects distal femur
Ewing's sarcoma	Affects children 5–15 years old; bony pain, fever, fatigue, weight loss, pathologic fractures, palpable mass

What Is the Most Likely Diagnosis?

The most likely diagnosis is slipped capital femoral epiphysis (SCFE). There are a number of factors from the patient's history and physical exam that support this diagnosis (discussed below).

History and Physical

What Important Demographic Factor Limits the Differential Diagnosis for This Patient?

Age. Certain tumors or metastases which commonly affect the proximal femur in adults such as multiple myeloma or those that commonly spread to bone (recall the common

“BLT and Kosher Pickle” mnemonic for breast, lung, thyroid, kidney, and prostate) can immediately be eliminated given the patients’ age. Other tumors like acute lymphoblastic leukemia or neuroblastoma, which may present with joint pain initially, primarily occur in children younger than 5 years. Among the mechanical processes, transient synovitis peaks at 2–5 years (max around 12) and Legg-Calve-Perthes at 4–8 years. Also, it would be highly unusual for developmental dysplasia of the hip (DDH) to have its first presentation at age 12 years (screening for these begins at birth using Ortolani and Barlow maneuvers, with ultrasound and orthopedic follow-up for any suspected abnormality). Coupled with the absence of fever and other constitutional symptoms, only a few diagnoses remain for groin pain with a painful limp in a 12-year-old.

What Is an Antalgic Gait?

Limping due to pain is referred to as an antalgic gait and is associated with a short stance phase on the affected limb. The patient wants to spend the least time needed on the painful limb to allow ambulation.

What Risk Factors Are Shared by Patients That Develop SCFE?

SCFE commonly presents at age 10–16 years old, males are more commonly affected than females (2:1), and the condition is more common among blacks and Polynesian ethnicities. *Obesity* is one of the strongest risk factors, presumably due to an increased load across the physis. 50% of SCFE patients are >90th percentile for weight; 70% of patients are >80th percentile.

What Is the Most Common Presentation of SCFE and Physical Exam Findings?

Children commonly present with an antalgic gait (painful limp) and occasionally an inability to bear weight because of pain. Pain associated with SCFE most commonly presents at the groin but can also radiate and localize to the thigh or knee. On physical exam, SCFE patients present with decreased internal rotation, and the thigh is held most comfortably resting in external rotation. Internal rotation maneuvers recreate the pain. Though a painful limp can be a sign of tumor or infection, the absence of fever, malaise, and other constitutional symptoms make these less likely.

What Is the Significance of External Rotation of His Leg and Resisting Internal Rotation?

External rotation of the leg is the most common resting position of children with SCFE because of the direction in which

the metaphysis slips in relation to the epiphysis. Often, this external rotation can be exaggerated when the hip is brought into flexion and the leg involuntarily externally rotates. This is called obligatory external rotation.

What if the Patient Holds the Thigh in Slight Hip Flexion and Internal Rotation?

This position is classic for a psoas abscess with reflexive contracture of the psoas muscle due to spasm, especially in conjunction with fever and other signs of infection. Attempts at passive hip extension which stretch the psoas muscle are usually met with significant pain and resistance. Psoas abscess is often a sign of another underlying etiology such as osteomyelitis of the spine, appendicitis, or Crohn’s. Thus, once the diagnosis of a psoas abscess is determined, it is important to search for the primary source of the abscess.

Watch Out

A hip held in flexion and internal rotation after a traumatic event and without signs or symptoms of infection is a hip dislocation until proven otherwise and is a surgical emergency. Hip dislocations carry a real risk of avascular necrosis.

Why Is It Important to Examine the Hip in the Setting of Knee Pain?

Hip pathology may cause referred pain to the knee. Legg-Calve-Perthes disease and SCFE can both initially present as knee pain, with no complaint of hip discomfort. Therefore, it is important to perform a complete physical exam to determine if knee pain is native to the knee or referred from the hip.

Watch Out

In younger pediatric patients, a complaint of knee pain should always lead to clinical and radiographic examination of the hip.

Why Is It Important to Consider Delayed Growth, Puberty, or Endocrinological Signs or Symptoms if SCFE Is Suspected?

SCFE typically presents in overweight patients older than 10 years. Patients who are young (<10 years old) or thin (<50th percentile for weight) should be worked up for an underlying endocrinological disorder. Several endocrine disorders are associated with SCFE in these atypical patients, including hypothyroidism, growth hormone abnormalities,

renal osteodystrophy, hypopituitarism, and hyper- or hypoparathyroidism. These conditions physiologically weaken the physis which increases the likelihood of slippage.

What Is the Significance of Pain That Radiates into the Groin?

In this patient, the pain originates in the groin and radiates to the thigh toward the knee (thought to be via the obturator nerve). Pain *originating* in the groin is highly suggestive of pathology in or around the hip joint. Pain that *radiates* to the groin is not typical of hip disease and suggests other pathology, particularly urologic, reproductive, or spinal etiologies.

Watch Out

Hernias, testicular disease, and kidney stones are important entities that cause pain which radiates to the groin.

Why Is It Important to Clarify the Meaning of Hip Pain on History?

The average patient thinks hip pain is proximal and lateral thigh pain near the greater trochanter or buttock. The hip joint itself (femoral head articulation with the acetabulum) is well medial to this, and pain should be felt in the groin region, as expected from its anatomic position. If clarification reveals a lateral or buttock origin for the pain, then trochanteric bursitis, neurogenic claudication, sciatica, or sacroiliac joint pathology should be considered.

Watch Out

The shoulder is similar to the hip in that true glenohumeral arthritis is felt in the axilla (the armpit or “groin” of the shoulder). Unlike the hip joint where arthritis is common, musculoskeletal shoulder disease more commonly involves the rotator cuff or subacromial bursa, which is felt laterally over the shoulder akin to trochanteric bursitis of the hip.

What Would Be the Significance of a History of a Recent Upper Respiratory Tract or Other Viral Infection?

A recent history of upper respiratory tract infection (URI) or viral infection in the presence of hip pain would suggest a post-infectious inflammatory etiology, such as *transient synovitis*. Transient synovitis is the most common cause of hip pain during childhood, and though most common under

5 years of age, it can be seen into late adolescence. The pain is usually worse upon awakening and improves as the day progresses. As opposed to septic arthritis, transient synovitis presents with a mild or absent fever. The treatment for transient synovitis is usually observation, as this condition is self-limiting. Note that this is a diagnosis of exclusion, and a full workup for septic arthritis, including aspiration if needed, should be done if there is any doubt.

Why Is It Important to Ask About Travel or Exposure to Wildlife?

Recent travel or exposure to wildlife can raise the concern for special cases of septic arthritis. Travel outside the United States can risk exposure to tuberculosis (TB). Children with TB are more likely than adults to present with extrapulmonary involvement. The most common site of musculoskeletal involvement is the spine, followed by large joints (hip, knee). Domestically, exposure to wildlife in the upper Midwest and New England can raise the concern for Lyme disease. Children with Lyme arthritis are usually able to bear weight, and the pain is typically less severe than with typical bacterial arthritis. A target-shaped rash, erythema migrans, presents in the early stages of Lyme disease and is very helpful for early detection if seen.

Why Is a Family History of Joint Disease Important?

Family history of joint pain is an important clue for some disease processes. Developmental dysplasia of the hip (DDH) is thought to be largely multifactorial; however, family history is a strong risk factor. There is a 12% risk of DDH when at least one parent is involved and a 36% risk when both parents have a history of DDH. Additionally, juvenile idiopathic arthritis often has a genetic component.

Watch Out

A *non-painful* limp while walking is common in early DDH and many neurological disorders.

Why Would a History of Corticosteroid Use Be Important?

A history of steroid use can predispose the pediatric population to *avascular necrosis* of the femoral head, also known as *osteonecrosis*. An adequate history is important because this diagnosis is clinically similar to Legg-Calve-Perthes disease (discussed in ► Sect. 32.4), which has an entirely different treatment algorithm.

What Are Other Important Risk Factors for Secondary Osteonecrosis of the Hip?

In pediatric patients, sickle cell disease and marrow-replacing processes like Gaucher's disease are important risk factors. In adults, alcoholism, dysbarism (decompression sickness, "the bends," or caisson disease), antiretroviral medications, previous history of hip trauma, and corticosteroid use are important etiologies to consider in the differential.

What Is the Significance of a Leg Length Discrepancy with This Clinical Presentation?

Leg length discrepancy (LLD) points toward a mechanical pathology. Disruptions in the structural integrity of the long bones of the lower limb can lead to LLD. This is common in DDH and Legg-Calve-Perthes disease. Infections, tumor, or trauma can lead to disruption of the physis or bone, ultimately leading to a LLD, but not in the acute phase. SCFE may have a mild or apparent LLD due to the posture of the hip and thigh.

Why Is It Important to Examine the Back?

A child with a long-standing LLD can develop a compensatory scoliosis.

What Is the Importance of the Ability to Bear Weight or Range the Hip?

The inability to bear weight or move through a range of motion for the hip indicates a potentially serious condition. Septic arthritis presents as the refusal to walk or bear weight in the setting of high fever. SCFE can present in a patient with or without the ability to bear weight. The inability to bear weight is what differentiates an *unstable* SCFE from a stable one. An unstable SCFE has a significantly higher rate of osteonecrosis of the femoral head as compared to a stable one. Both types of patients require surgical intervention on an urgent basis.

What Are the Component Steps in the Orthopedic Examination of a Painful Hip?

Gait, observation/inspection, palpation, range of motion (active, passive), neurologic (motor, sensory), vascular (pulses), and special physical exam tests

What Are Some Common Physical Exam Tests Utilized in the Examination of the Hip?

Table 32.2

Test	Comments
<i>Thomas test for flexion contracture</i>	Patient lies supine and brings one knee to chest; if opposite leg is unable to remain completely extended, then this is indicative of a flexion contracture of the hip
<i>Trendelenburg test</i>	Patient in standing position and asked to lift one leg; the pelvis should remain level but if falls or dips inferiorly on the side of the raised leg, this is indicative of abductor muscle weakness on side of standing leg
<i>FABER</i>	Flexion, abduction, external rotation maneuver of the hip while patient is supine; if this position results in pain, it suggests sacroiliac joint pathology

Pathophysiology

What Is the Pathophysiology for the Orthopedic Mechanical Diagnoses?

Table 32.3

Diagnosis	Pathophysiology and features
<i>Developmental dysplasia of the hip</i>	Abnormal hip development resulting in laxity, subluxation, or dislocation of the hip; initial instability/laxity of the hip results in malpositioning of the femoral head in the developing acetabulum and incomplete formation of the hip socket; dysplasia can lead to gradual dislocation, difficulty with ambulation, degenerative arthritis, and pain
<i>Legg-Calve-Perthes disease</i>	Unknown pathophysiology; idiopathic osteonecrosis of femoral head; typically presents at age 4–8 years
<i>Stress fracture</i>	Repetitive overloading causing a fatigue fracture which overwhelms the body's remodeling and repair capacity, typically minimally or non-displaced
<i>Slipped capital femoral epiphysis</i>	Displacement of the metaphysis of the femoral neck from the epiphysis of the femoral head through the growth plate/physis, likely due to obesity and overloading of the physis, less commonly due to a weakened growth plate from an endocrinological disorder; the femoral neck displaces anteriorly and superiorly relative to the femoral epiphysis; typically, presents at age 10–16 years

Are “Shin Splints” the Same as Tibial Stress Fractures?

No. Medial tibial stress syndrome (shin splints) presents with *diffuse* tenderness along the tibia of overweight individuals that are on their feet for a prolonged period of time (e.g., security guard). In contrast, a tibial stress fracture presents with *focal* tenderness along the anterior tibia worsened with exercise and occurs in individuals with a sudden increase in activity (e.g., new gym membership). Radiographs are often normal.

Watch Out

Stress fractures of the metatarsals can also occur after sudden increases in activity. The second metatarsal is the most commonly injured, and most patients only require rest and analgesia. The fifth metatarsal is the only one that has increased risk for nonunion and so may require surgical intervention.

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Workup

What Laboratory Tests Would Be Useful and Why?

Laboratory values are important to determine the etiology of musculoskeletal pathology. In this case, one must rule out infection via laboratory testing. Complete blood count, complete chemistry panel, ESR, and CRP should be drawn to check for signs of infection. Septic arthritis in the pediatric population can be diagnosed using the Kocher criteria (■ Table 32.4). The predicted probability of septic arthritis is 5% with one predictor, 40% with two predictors, 95% with three predictors, and 99% with all four predictors. Additionally, a CRP >2.0 mg/dl coupled with refusal to bear weight carries a 75% probability of septic arthritis. Blood cultures and joint aspirations should be drawn if there is a suspicion of infection.

■ **Table 32.4** Kocher criteria to diagnose septic arthritis in pediatric population

Fever >38.5 C
Inability to bear weight
ESR >20 mm/h
WBC >12,000/μl

What Analysis Should Be Done if Joint Aspiration or Arthrocentesis Is Done for Suspected Infection?

Samples of joint fluid should be sent for cultures, including aerobic and anaerobic bacteria, fungi, and mycobacteria. Gram stain, fungal prep, and acid-fast stains must be done in addition to culture. It is also important to perform cell counts and crystal analysis.

What Is the First Imaging That Would Be Recommended?

Plain film radiographs (x-rays) should be ordered first. AP and frog-leg lateral views of the pelvis should be ordered for any suspected hip pathology. If knee pathology is in question, additional plain radiographs of the knee are ordered (AP, lateral, sunrise views). In pediatric populations, a complaint of hip or knee pain should both prompt hip radiographs.

What Are the Classic X-ray Findings of Pediatric Orthopedic Mechanical Hip Disease?

■ **Table 32.5**

Disease	X-ray finding
<i>Developmental dysplasia of the hip</i>	Subluxation or dislocation of the femoral head from the acetabulum; difficult to assess on x-ray in infants, for which ultrasound is typically used (■ Fig. 32.1)
<i>Legg-Calve-Perthes disease</i>	Subchondral (under the cartilage) collapse of the bone of the femoral head
<i>Slipped capital femoral epiphysis</i>	Asymmetry of the femoral head on the neck. The appearance is commonly described as “ice cream sliding off the cone” (■ Figs. 32.2 and 32.3)

What Other Imaging Is Useful if the Diagnosis Is Unclear?

MRI is excellent at visualizing non-displaced stress fractures, early avascular necrosis, or Legg-Calve-Perthes disease, as well as soft-tissue abnormalities of the ligaments, tendons, and labrum. MRI also adds to the workup for local tumors

and osteomyelitis about the hip. CT is excellent for fine evaluation of bone but is used sparingly in children to avoid unnecessary radiation exposure. CT of the chest, abdomen, and/or pelvis is used in the workup of malignant tumors to assess for metastases. Bone scans evaluate the metabolic

activity of the bone by recording uptake of venous-injected radioactive material (i.e., technetium-99 m). They can be used to highlight an active area of infection or tumor, when the lesion is not otherwise evident (e.g., an osteoid osteoma: a small, but painful, benign bone tumor).

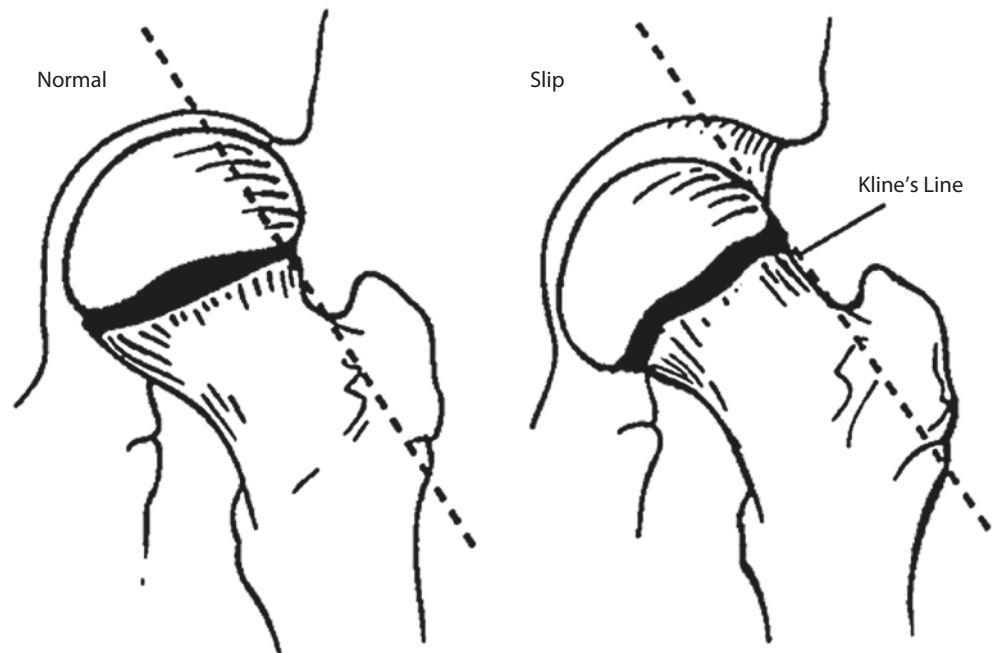


■ **Fig. 32.1** Developmental dysplasia of the hip radiograph showing normal right and subluxated left hip



■ **Fig. 32.3** SCFE radiograph (frog lateral) showing SCFE on left and normal right

■ **Fig. 32.2** SCFE schematic



Management

What Is the Management for the Following Diagnoses on the Differential?

Table 32.6

Infectious	Management
Septic arthritis	Joint aspiration and blood cultures will dictate antibiotic selection but start with broad-spectrum IV antibiotics; emergent incision and drainage
Lyme disease	Antibiotics (doxycycline, amoxicillin, or cefuroxime)
Psoas abscess	Antibiotics +/- surgical drainage
Inflammatory	
Juvenile idiopathic arthritis	DMARDs, NSAIDs, +/- steroid injections, frequent ophthalmologic exams; watch for C1–2 instability and myelopathy; as disease progresses, surgery for diseased joints is often necessary
Transient synovitis	Observation and NSAIDs; rule out septic arthritis
Mechanical	
Developmental dysplasia of the hip	0–6 months: Pavlik harness 6–18 months: surgical closed vs. open reduction with spica casting >18 months: surgical open reduction with pelvic osteotomies
Legg-Calve-Perthes disease	Most patients do not require treatment (symptomatic and supportive measures); treatment of advanced disease aims at <i>containment</i> (casting/bracing, femoral/pelvic osteotomies)
Stress fracture	Period of non- or protected weight bearing +/- casting/bracing
Slipped capital femoral epiphysis	In situ screw fixation across the capital physis
Neoplastic	
<i>Benign</i>	
Osteoid osteoma	Percutaneous RFA if symptoms not controlled with NSAIDs
Other benign bone lesions	Observation vs. intralesional curettage and grafting
<i>Malignant</i>	
Osteosarcoma	Neoadjuvant chemotherapy plus wide surgical resection
Ewing's sarcoma	Neoadjuvant chemotherapy plus wide surgical resection, possible radiation
DMARD disease modifying antirheumatic drugs, NSAID nonsteroidal anti-inflammatory drugs, RFA radiofrequency ablation	

Complications

What Are the Important Potential Complications of Surgery for SCFE?

Most patients with SCFE undergo percutaneous screw fixation of the femoral head. The area for the screw placement is very small, and it is sometimes difficult to obtain purchase across the capital physis into the epiphysis from the femoral neck. If the screw is too long, it may penetrate the hip joint and destroy the cartilage and lead to chondrolysis. If the screw is too short, further slippage may occur, often necessitating additional, more involved surgeries to correct the alignment of the hip. Avascular necrosis of the femoral head due to disruption of the blood supply is also a dreaded complication.

Area of Controversy

Do Both Hips Require In Situ Screw Fixation in Patients with SCFE?

At the time of presentation, most patients present with unilateral SCFE (80%). Ultimately, bilateral involvement ensues in 10–60% of cases. When a patient presents with unilateral SCFE requiring surgical fixation, some surgeons support prophylactic fixation of the contralateral, unaffected hip. It has been suggested that contralateral fixation should be considered in high-risk patients. Patients with a high risk for slippage of the contralateral hip include those <10 years old, those with endocrinopathies, renal osteodystrophy, or a history of radiation therapy.

Area Where You Can Get in Trouble

Never Miss Septic Arthritis

Most of the conditions in the differential for this case do not require immediate intervention, though symptomatic SCFEs are typically admitted and surgically pinned on an urgent basis. The only exception to this rule is septic arthritis due to bacterial pathogens like *Staphylococcus* or *Streptococcus*, which is a surgical emergency. Irreversible cartilage damage leading to dysfunction of the joint can occur in a matter of hours, so every minute counts. Thus, it is important to investigate and attempt to rule out this diagnosis early in the workup. The patient's history and laboratory values are primarily used to make the diagnosis of septic arthritis. Fever with refusal to move or bear weight on the joint is septic until proven otherwise. Laboratory values can be used along with the Kocher criteria to confirm the diagnosis. Once septic arthritis is suspected, the patient should be taken to the OR for emergent debridement.

Summary of Essentials

History and Physical

- SCFE: Obese, adolescent male aged 10–16 years old presenting with groin pain, painful limp, externally rotated hip, and not irritable with gentle flexion or extension.
- Knee pain is referred from hip pathology in young children until proven otherwise.

Pathophysiology

- Excess loading across the physis causes slippage of the epiphysis on the metaphysis of the proximal femur in SCFE
- Predisposing factors for weak physis in SCFE:
 - Endocrine disorders
 - Osteodystrophy
 - Hypothyroid/hypopituitarism

Workup

- SCFE confirmed by displacement of proximal femoral epiphysis from metaphysis, seen on AP and/or frog lateral view of the hip.
- Rule out emergent septic arthritis.

Management

- Admission to hospital for urgent in situ surgical pinning of the hip
- Short period of protected weight bearing with crutches

Complications

- Screw too short or long, inadequate fixation, additional slippage, avascular necrosis

Suggested Reading

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Chronic Right-Hand Pain

Arezou Yaghoubian and Kevin W. Rolfe

Case Study

A 45-year-old seamstress presents to the clinic with a 4-year history of paresthesias of the volar right thumb, index, and middle finger with associated pain. She reports that the symptoms are worse at night. She has no past medical history and no history of cancer. On examination, she has decreased sensation on the volar thumb, index, and middle finger as well as the dorsal finger tips and a positive Tinel's sign and Phalen's test at the wrist. Strength in her abductor pollicis brevis is abnormal at 3/5 compared to the contralateral side, and she has moderate thenar atrophy but no hypothenar or intrinsic muscle atrophy. The hand is well perfused, and there are no surgical or traumatic scars of the hand or wrist. Bilateral radial and ulnar pulses are normal.

Diagnosis**What Is the Differential Diagnosis?**

■ Table 33.1

Etiology	Differential diagnosis
<i>Vascular</i>	Thoracic outlet syndrome, compression of brachial plexus by ribs or muscle
<i>Infectious</i>	Medical neuropathy (e.g., leprosy, Lyme disease, HIV, hepatitis, post-herpetic neuralgia)
<i>Neoplastic</i>	Pancoast tumor invading brachial plexus, intracranial neoplasm, peripheral nerve tumor (e.g., schwannoma)
<i>Inflammatory or degenerative</i>	Cervical root pathology (radiculopathy), cervical cord pathology (myelopathy), carpal tunnel syndrome, pronator syndrome, cubital tunnel syndrome, ulnar tunnel (Guyon's canal) syndrome, radial neuropathy
<i>Traumatic</i>	Injury (median nerve, brachial plexus, spinal nerve or cord), post-traumatic syring, CRPS/RSD
<i>Iatrogenic/drugs</i>	Local radiation-induced or systemic chemotherapy-induced plexopathy or neuropathy, injury from prior surgery
<i>Metabolic/endocrine</i>	Diabetic or other medical peripheral neuropathy including hypothyroidism, vitamin deficiency, heavy metal or other toxicity
<i>Autoimmune</i>	Multiple sclerosis, Guillain-Barré syndrome, sarcoidosis

HIV human immunodeficiency syndrome, CRPS complex regional pain syndrome, RSD reflex sympathetic dystrophy

What Clues on History and Physical Examination Might Direct You Toward Specific Diagnoses?

■ Table 33.2

Diagnosis	History and physical
<i>Thoracic outlet syndrome</i>	Positive Adson's or Wright's test, ulnar nerve symptoms most likely
<i>Medical neuropathy (infectious, metabolic, iatrogenic)</i>	Often diffuse and bilateral; history of cancer or its treatment, HIV, diabetes, nutritional deficiency, or toxic exposure
<i>Traumatic</i>	Acute injury with new onset of symptoms usually obvious; CRPS/RSD occurs later to a previously injured area that never fully recovered
<i>Autoimmune</i>	Generalized symptoms including diffuse weakness (multiple sclerosis, Guillain-Barré syndrome) or other systemic findings involving lung (sarcoid) or eye (MS)
<i>Cervical root</i>	Dermatomal distribution (vs. peripheral nerve), positive Spurling's test
<i>Cervical myelopathy</i>	Hyperreflexia, hand clumsiness, and gait unsteadiness on exam
<i>Carpal tunnel</i>	Positive Tinel's, Phalen's, or Durkan's test; median distribution of sensory symptoms
<i>Pronator syndrome</i>	Overlaps carpal tunnel, palmar cutaneous branch over thenar eminence also affected
<i>Other compressive neuropathies</i>	Radial or ulnar syndromes affect their respective peripheral nerve distributions or muscles; key is remembering the anatomy and innervation

HIV human immunodeficiency syndrome, CRPS complex regional pain syndrome, RSD reflex sympathetic dystrophy

What Is the Most Likely Diagnosis?

Carpal tunnel syndrome (CTS). Nighttime dysesthesias in the median nerve distribution to only one hand without prior injury or congenital defect, particularly in association with isolated thenar muscle wasting, are most likely due to CTS and are highly specific for this clinical entity. The differential diagnosis is very broad as CTS rarely presents exactly in the median nerve distribution, is often bilateral, and often occurs in association with other overlapping aches, pains, and medical conditions such as diabetes. This makes the diagnosis more challenging.

History and Physical

What Is the Most Common Nerve Entrapment Syndrome in the Upper Extremity?

CTS. The condition affects approximately 1% of the general population and 5% of the working population engaged in repetitive motion and grasping activities. Reports of prevalence of up to 25% or more have been made for full-time computer operators.

What Are the Major Risk Factors for CTS?

Women are affected 2–3 times more often than men with the most common age range of 40–60 years. Other risk factors include obesity, pregnancy, smoking, activities involving repetitive movements or sustained wrist flexion or extension, rheumatoid arthritis, hypothyroidism, and alcoholism. There is also a higher incidence among certain metabolic disorders like chronic kidney disease.

What Are Key Components in the Hand History Portion of the Exam?

Length of symptoms, sensory distribution of symptoms, history of dropping things, occupation or activity, nighttime symptoms (or worse at night, often needing to shake or wring the hands out vigorously), previous treatments (corticosteroid injection, wrist splints), and hand coordination.

What Are the Best Known Classic Signs of CTS?

Tinel's sign and Phalen's test. *Tinel's sign* is elicited by gently percussing over the median nerve at the carpal tunnel. A positive sign is present if the patient describes an electrical shock sensation in the median nerve distribution. *Phalen's test* is performed by having the patient place the dorsal sides of each hand against each other in a position of maximal wrist flexion for 30–60 seconds. The test is considered positive if the patient reports new or worsening paresthesias in the median nerve distribution of the affected hand(s).

What Is Durkan's Median Nerve Compression Test?

Durkan's involves squeezing the patient's wrist with direct compression over the median nerve at the carpal tunnel using the examiner's thumb. A positive test is obtained if the patient reports new or worsening numbness or tingling in

some portion of the median nerve sensory distribution to the hand within 30–60 seconds. This is thought to be the most sensitive test for CTS.

Are There Any Other Overlapping Median Nerve Diagnoses to Consider?

Proximal median nerve compression at the elbow often referred to as pronator teres syndrome, acute CTS, traumatic median nerve injury, or median nerve tumor (e.g., schwannoma).

What Is Acute CTS?

Acute CTS may be seen after a fracture or dislocation of the distal radius or wrist with acute compression of the median nerve.

Watch Out

Acute CTS is an emergency and requires immediate reduction of the fracture or dislocation and often surgical release of the carpal tunnel.

What Physical Exam Finding Helps Distinguish Proximal Median Nerve Compression at the Elbow (Pronator Teres Syndrome) from Compression at the Carpal Tunnel?

The palmar cutaneous branch of the median nerve branches prior to the carpal tunnel and travels above the transverse carpal ligament. It innervates the skin over the thenar eminence. Thus, typical CTS will not show sensory dysesthesias in this area, whereas pronator teres syndrome will.

What Findings Help Distinguish CTS from Cervical Spine Root Pathology?

Much like the straight leg raise for sciatica of the lumbar spine, *Spurling's test* may be used to elicit cervical root pathology (radiculopathy). The patient is asked to extend the neck and tilt and turn the head laterally to the affected side to determine if the hand dysesthesias occur or worsen with the maneuver.

Watch Out

C-6 and C-7 nerve roots overlap the median nerve distribution to the hand and are often confused with it. A key sensory distinction is that CTS does not affect the dorsal hand except for the finger tips. C-6 and C-7 nerve roots also affect the dorsum of the hand in the radial nerve distribution in addition to the median distribution.

What Is Thoracic Outlet Syndrome and What Physical Exam Tests Distinguish It from Spinal Root Pathology?

Thoracic outlet syndrome (TOS) involves compression of the lower brachial plexus (ulnar symptoms predominate) or compression of the subclavian vessels between the anterior and middle scalene muscles, often associated with a *cervical rib* (obtain CXR to look for this). Two classic tests are used, Adson's and Wright's, both of which are frequently confused with the Spurling's test. *Adson's test* involves extension of the shoulder with the neck turned *toward* the affected side and may reproduce TOS symptoms or cause reduction or loss of the pulse at the wrist. *Wright's test* involves abduction and external rotation of the shoulder with the neck rotated *away* from the affected side and may similarly reproduce TOS symptoms or cause reduction or loss of the pulse at the wrist.

Watch Out

Look for a Pancoast tumor of the lung on x-ray if the presentation suggests thoracic outlet syndrome symptoms or brachial plexopathy.

What About Myelopathy?

Myelopathy is a dangerous and irreversible entity that often presents with hand pains or dysesthesias but not neck pain. It should always be considered, especially when the hand pains do not follow an exact pattern of CTS. Hyperreflexia (and pathologic reflexes like Hoffmann's or suprapatellars) and heel-toe tandem gait should be checked. The patient may likewise complain of dropping things but also incoordination of the hands for fine motor skills and decreased balance during ambulation. Many patients are referred to hand surgeons for alleged CTS which is really myelopathy. A neurologic exam is key, especially reflexes.

Pathophysiology

What Nerve Is Compressed in CTS?

The median nerve is compressed in CTS.

What Is the Motor Distribution of the Median Nerve in the Hand?

Median nerve innervates the thenar muscles (abductor pollicis brevis; flexor pollicis brevis, superficial head; and opponens pollicis) and the two radial lumbricals.

What Is the Sensory Distribution of the Median Nerve in the Hand?

Sensory distribution provides sensation to the radial volar 3½ fingers and dorsal tips (thumb, index, middle, and half of the ring).

Watch Out

Finger numbering is not used by hand surgeons as it is unclear. Always label the digits as thumb, index, middle, ring, and small fingers. If numbers are used, the thumb is 1, index 2, middle 3, ring 4, and small 5 by convention, but bear in mind numbers are not ideal.

What Is the Origin of the Median Nerve from the Cervical Spine Roots?

The origin of the median nerve from the cervical spine roots is C5-T1.

Where Is the Median Nerve Located in the Wrist?

The median nerve is located in the carpal tunnel.

What Are the Boundaries of the Carpal Tunnel?

Carpus dorsally (floor) and transverse carpal ligament volarly (roof). The scaphoid, trapezium, and sheath of flexor carpi radialis form its radial margin. The ulnar boundary consists of the triquetrum, hook of the hamate, and the pisiform.

How Many Structures Course Through the Carpal Tunnel, and What Are the Contents of the Carpal Tunnel?

Ten structures (nine tendons and one nerve). Flexor digitorum superficialis (four), flexor digitorum profundus (four), flexor pollicis longus (one), and the median nerve (one).

Watch Out

The median nerve is the most *superficial* structure in the carpal tunnel.

What Is the Pathophysiology of CTS and Potential Causes?

It is idiopathic or unknown. The primary reason leading to the development of CTS is an increase in the interstitial pressure in the carpal tunnel that affects the median nerve. This increased pressure has numerous purported causes. In the vast majority of cases, however, no underlying etiology is identified despite the presence of pathologically inflamed synovial tissue.

What Is the Significance of Thenar Wasting?

Since the recurrent motor branch of the median nerve innervates the thenar muscle mass, long-standing or severe CTS can result in denervation of the thenar muscles. The profile of the thenar eminence of both hands as well as the strength of abductor pollicis brevis (palmar abduction) should always be checked.

What Are the Three Stages of Median Nerve Compression, and Why Are They Important?

Stage 1: Sensory symptoms (numbness, pain, tingling) at night. Stage 2: Symptoms occur also by day. Stage 3: Motor symptoms of weakness and/or muscle wasting, too. The importance is that later stages, especially stage 3, may not show positive findings like Tinel's, Phalen's, or Durkan's test. The nerve is no longer hyper-excitable but dying and hypo-excitable and does not respond to these maneuvers. These stages account for much of the variability in the sensitivity and specificity of these exam signs. As important, later stages of CTS, like myelopathy, are largely irreversible, and surgical intervention should be entertained early to prevent progression.

How Does the Presentation of a Median Nerve Lesion at the Elbow Differ from a Lesion at the Wrist?

Do not confuse CTS with the lesions described after acute laceration or injury to a nerve at the wrist or elbow, whether median or ulnar, which result in various claw deformities or dysfunctions. A median nerve laceration at the elbow results in the "hand of benediction" *when trying to form a fist*. Since the flexor digitorum profundus (FDP) tendons to the index and middle finger, as well as the flexor pollicis longus (FPL) to the thumb, do not function in a high median nerve lesion (elbow), only the ring and small fingers form the fist, and the hand looks like that of hand of benediction when trying to do so. The hand of benediction would not occur in a low median nerve lesion at the wrist below the innervation of those muscles.

What About the Ulnar Claw?

Clawing of the hand refers to extension of the metacarpophalangeal (MP) and flexion of the interphalangeal (IP) joints of the hand. Three sets of intrinsic muscles normally afford counterbalancing MP flexion and IP extension (i.e., palmar interossei, dorsal interossei, and lumbricals). In an ulnar claw, all intrinsic muscles are denervated except the radial two lumbricals. Thus, the index and middle finger are slightly less affected.

Watch Out

Though a high ulnar lesion is worse than a lower one prognostically, a high lesion has a less severe hand claw as the FDP tendons of the ring and small fingers are also denervated, and so this lessens their resting tone contribution to the claw through IP joint flexion.

What Is Froment's Sign?

Froment's sign is positive (abnormal) when the examiner can easily pull a flat piece of paper from the hand of the patient who uses thumb IP flexion via the FPL tendon of the median nerve (anterior interosseous branch) to grasp the paper. This occurs in an ulnar palsy when the strong thumb adductor which would normally hold the paper firmly between the thumb and the side of the index finger (i.e., key pinch, as in the manner in which a key is held in the hand) is denervated.

What Systemic Condition Is Often Associated with CTS?

Hypothyroidism. No study clearly defines the relationship between hypothyroidism and CTS. One proposed mechanism involves the associated myxedema seen in patients with thyroid disease. The excess deposition of glycosaminoglycans and hyaluronic acid in subcutaneous tissue and the median nerve sheath may contribute to the development of CTS.

Workup

How Is Carpal Tunnel Diagnosed?

Exam and history. Semmes-Weinstein filament testing (as for diabetic or neuropathic feet) is the most sensitive sensory modality. Electromyography/nerve conduction studies (EMG/NCS) are useful in equivocal cases, typically due to an uncertain distribution of the symptoms. Classic findings on

NCS are increased latencies and decreased conduction velocities across the wrist. EMG is most useful to rule out other pathologies. EMG may show slowing of median sensory or motor nerve conduction velocity at the wrist, prolonged distal motor or sensory latency, or denervation of the abductor pollicis brevis muscle.

Do Any Medical Neuropathies Need to be Ruled Out?

There are myriad medical neuropathies which may need to be ruled out and which may overlap with CTS. Remember, CTS often presents in an inexact distribution or bilaterally and often in association with an aging person with overlapping clinical entities. The approach of the neurologist is to rule out treatable causes of neuropathy before embarking on symptomatic treatment using drugs like gabapentin. The workup will include EMG/NCS, multiple screening labs (vitamin deficiency, heavy metal or other toxicity, infection, thyroid disease, etc.), spinal tap, and/or nerve biopsy. Highly testable laboratory screening items include vitamin B12 (subacute combined degeneration of the cord), RPR for syphilis (tabes dorsalis), HIV, thiamine (alcoholism), TSH for thyroid disease, ANA (autoimmune disease), HbA1c (diabetes), and CRP (inflammatory process).

How is Suspected Cervical Spine Disease Worked Up?

MRI and x-rays of the cervical spine would evaluate root or cord pathology.

Watch Out

If patient cannot have a MRI due to an incompatible stent, pacemaker, etc., then the test of choice for spinal pathology is a CT *myelogram*. This involves a dural puncture and injection of contrast into the thecal sac to outline the spinal cord and nerve roots. It is not the same as a CT with intravenous contrast injected peripherally.

Management

What Is the Initial Treatment for CTS?

Splinting of the wrist (not hand) in a neutral position. This position affords the lowest pressure in the carpal tunnel. NSAIDs and activity modifications are also first-line treatment modalities.

What Is the Second Line of Treatment?

Carpal tunnel injection with local anesthetic and corticosteroid medication. Response to steroid injection is a good prognostic indicator for improvement with surgery, if required later. Similarly, failure to respond to injection (at least temporarily) suggests surgery is unlikely to improve symptoms.

What Are Indications for Surgical Intervention for CTS?

Failure to respond adequately to conservative nonoperative management or thenar motor involvement is an indication for surgical intervention for CTS.

Watch Out

Thenar atrophy or denervation of the abductor pollicis brevis muscle on EMG should prompt early surgical treatment as these are late-stage findings and largely irreversible. Surgery is primarily to prevent progression at this point.

What Is the Gold Standard Treatment for CTS?

Carpal tunnel release which is surgical cutting of the transverse carpal ligament, the roof of the carpal tunnel. This is performed through a small open incision or endoscopically. Neurolysis or manipulation of the median nerve and its tissue coverings *does not* improve outcomes and is not typically performed.

How Is CTS Associated with Hypothyroidism Managed?

This is initially treated conservatively with splinting of the wrist in a neutral position and NSAIDs while the hypothyroidism is treated. Typically, once the hypothyroidism is resolved, so will the CTS.

Complications

What Are the Complications of Carpal Tunnel Release?

Injuries to the median nerve, recurrent motor branch, or palmar cutaneous branch; chronic pain including neuroma, scar, or CRPS/RSD; injury to the superficial palmar vascular arch, infection, hematoma, inadequate release, and recurrence.

Areas of Controversy

Endoscopic Versus Open Carpal Tunnel Release

Though long-term outcomes are equivalent, endoscopic release affords a quicker surgical recovery. However, the endoscopic technique has a higher rate of inadequate release of the transverse carpal ligament.

Need for EMG/NCS

CTS is a clinical diagnosis and EMG/NCS is not required to treat it. It adds additional cost and is an uncomfortable test for most patients. When the diagnosis of CTS is less clear, it is a valuable test to consider, but practitioners vary as to their threshold to order the test.

Areas Where You Can Get in Trouble

What Is the “Million-Dollar Nerve”?

The recurrent motor branch of the median nerve can be injured if the transverse carpal tunnel ligament is transected too radially. This nerve has a variable anatomic course and sometimes runs through the ligament without recurring thereby increasing risk of its transection. It has been called the million-dollar nerve as iatrogenic injury to it has led to many million-dollar lawsuits. The thumb will show greatly impaired function if the nerve is injured.

Injury to the Palmar Cutaneous Branch

This nerve lies above the transverse carpal tunnel and helps distinguish proximal from distal median nerve compression as previously mentioned. It can be easily cut during surgical release of the carpal tunnel and may lead to a very painful and difficult-to-treat neuroma despite improvement in CTS symptoms.

Failure to Recognize Spinal Pathology

Though root pathology is important and may overlap CTS, myelopathy is largely irreversible and may lead to paralysis if masquerading as CTS. Both CTS and myelopathy often present with hand numbness or tingling and complaints of dropping

things. For myelopathy, check for hyperreflexia and gait imbalance and ask about hand incoordination like deterioration in fine motor skills of the hand-like handwriting.

Summary of Essentials

History

- Sensory dysesthesias in the median nerve distribution ($3\frac{1}{2}$ radial digits volar and dorsal tips), dropping things, symptoms worse at night time, job or activity involving repetitive movements of the hand/wrist

Physical Exam

- Tinel’s, Phalen’s, and Durkan’s tests.
- Check for thenar atrophy.

Pathophysiology

- Majority of cases are idiopathic involving synovial inflammation and increased pressure within the carpal tunnel.

Diagnosis

- Diagnosis is clinically based on history and exam.
- Equivocal cases should prompt EMG/NCS.
- Rule out spinal disease with MRI and medical neuropathies with laboratory testing as indicated based on history and exam.

Management

- NSAIDs, wrist splinting, carpal tunnel injection
- Surgical release (open or endoscopic) for cases that fail conservative treatment or if muscle involvement (thenar wasting) is present

Postoperative

- Painful scar or neuroma, injury to the recurrent motor branch, inadequate release (particularly endoscopic technique), and recurrence are important complications.

Additional Important Facts

- Beware of overlooking myelopathy or Pancoast tumor.
- Beware of overlooking a treatable peripheral neuropathy (e.g., syphilis, HIV, vitamin deficiency, heavy metal toxicity, cancer, rheumatologic condition, diabetes, thyroid disease).
- Beware of acute carpal tunnel syndrome, an emergency, after acute fracture or dislocation.

Suggested Reading

Bland JD. Carpal tunnel syndrome. *BMJ*. 2007;335:43.
MacDermid JC, Wessel J. Clinical diagnosis of carpal tunnel syndrome: a systematic review. *J Hand Ther*. 2004;17:309.

Question Set: Orthopedic Surgery

Questions

1. An obese 11-year-old presents to his pediatrician because his mother is concerned that he has been limping for the past day. He states that he is limping because of dull pain in his right knee. He has no history of preceding trauma. The pain is increased by physical activity. On physical exam, there is tenderness to palpation at the anterior hip along with limitation in internal rotation of the hip. Knee exam is normal. Plain films show subluxation of the right femoral head. Which of the following is the most appropriate definitive treatment?
- (A) Supportive therapy with rest and ibuprofen
 - (B) Aspiration of the synovial fluid along with appropriate antibiotic therapy
 - (C) Weight-loss program
 - (D) Operative stabilization
 - (E) Pavlik harness
2. An 18-year-old soccer player presents to her doctor 2 days after getting kicked in the knee during her championship game. She reports hearing a snap immediately after the injury, but her knee looked normal. The next day, she had a swollen kneecap with progressive pain. On physical exam, she has medial joint line tenderness and effusion. Her doctor notices an audible snap occurring when extending the knee from a fully flexed position while applying tibial torsion. What is the most likely diagnosis?
- (A) Collateral ligament tear
 - (B) Anterior cruciate ligament tear
 - (C) Stress fracture
 - (D) Tendon displacement
 - (E) Meniscus tear
3. A 32-year-old housekeeper comes to the physician for hip pain localized to the lateral aspect of the hip. The hip pain is interrupting her sleep. She denies any muscle weakness or numbness and tingling. The pain is not worse with physical activity. On physical exam, there is tenderness to palpation on the lateral aspect of her hip while in the lateral decubitus position. Which of the following is the most likely etiology of the hip pain?
- (A) Hip osteoarthritis
 - (B) Meralgia paresthetica
 - (C) Trochanteric bursitis
 - (D) Osteonecrosis
 - (E) Hip fracture
4. A 17-year-old male comes to the emergency department for the third time over the last month due to pain in his right thigh above his knee that is particularly bothersome at night. He was previously diagnosed with growing pains. Now he has developed swelling above his right knee and states his pain is worse. On physical exam, there is a soft tissue mass that is tender to palpation. The skin overlying the mass is erythematous. An x-ray is obtained and shows a "sunburst" pattern in the distal femur. What is the most likely diagnosis?
- (A) Ewing's sarcoma
 - (B) Osteosarcoma
 - (C) Osteomyelitis
 - (D) Osteochondroma
 - (E) Osteoid osteoma

5. After a physical exam, what is the most appropriate study in order to help work up a patient with pain following valgus stressing of the knee?
- (A) MRI
 - (B) CT
 - (C) Radiograph
 - (D) Arthroscopy
 - (E) Nerve conduction studies
6. An ambitious young female surgeon decided to travel to Armenia with an international medical team to provide services for patients that have not had any previous medical attention. Her work involves traveling long distances by foot and standing up for many hours while performing minor and major surgeries for an intense 3-week period. After returning from the trip, she experiences fatigue and increasing pain upon palpation at the midpoint of her right leg that wakes her up at night. On physical exam, she has point tenderness in her proximal tibia with some surrounding edema of the skin. Plain x-ray of the tibia is negative. What is the most likely etiology for his pain?
- (A) Medial tibial stress syndrome (MTSS)
 - (B) Osgood-Schlatter
 - (C) Stress fracture
 - (D) Exertional compartment syndrome
 - (E) Osteomyelitis
7. A 45-year-old alcoholic male presents with fevers and right-hand pain. He cannot recall what happened but thinks he may have punched someone in the face during a bar fight 2 days earlier. He has tried over-the-counter anti-inflammatory agents, but they have not helped decrease the pain. His temperature is 37.7 °C, blood pressure is 132/88 mmHg, and pulse is 78/min. On physical exam, he has a skin break over his second phalanx-metacarpal region. He is holding his second finger in slight flexion. He has a sausage-shaped swelling of the finger, as well as flexor tendon sheath tenderness that extends the entire length of the tendon. His pain increases with passive motion of the finger. What is the most likely diagnosis?
- (A) Suppurative tenosynovitis due to *Eikenella corrodens*
 - (B) Gout
 - (C) Dupuytren's contracture
 - (D) Suppurative tenosynovitis due to *Pasteurella multocida*
 - (E) Felon
8. A 5-year-old boy is brought to the pediatrician because of left knee pain that is causing him to limp. His history is significant for severe asthma. He was recently hospitalized for a severe exacerbation requiring a prolonged steroid taper. On physical exam, his temperature is 37.6 °C, blood pressure is 88/56 mm Hg, pulse is 76/min, and respirations are 16/min. He has a normal knee exam. Labs are drawn and show WBC of $7.4 \times 10^3/\mu\text{L}$ (normal $4.1\text{--}10.9 \times 10^3/\mu\text{L}$) and hemoglobin of 12.7 g/dL (12–15 g/dL). ESR and CRP are within normal limits. Which of the following is the most likely diagnosis?
- (A) Septic arthritis
 - (B) Osteomyelitis
 - (C) Slipped capital femoral epiphysis (SCFE)
 - (D) Torn anterior cruciate ligament (ACL)
 - (E) Osteonecrosis of the hip
9. A college athlete presents with shoulder pain. He reports that he was injured during basketball practice 2 days ago when his teammate ran into his shoulder. On physical examination, he has an edematous left shoulder. The clinician passively abducts

the patient's shoulders to 90° and flexes to 30° while asking the patient to point his thumbs down. The patient is unable to smoothly lower the arm. What muscle is the clinician trying to evaluate?

- (A) Supraspinatus
- (B) Infraspinatus
- (C) Teres minor
- (D) Teres major
- (E) Subscapularis

10. A 45-year-old internet insurance salesman presents to his doctor with progressive pain in his left hand for 1 year. His pain is primarily limited to the left thumb and index finger. After finishing the physical examination, his doctor believes he has carpal tunnel syndrome (CTS). Which of the following did the doctor most likely find on physical examination to support this diagnosis?
- (A) Percussing the wrist elicits pain in all five fingers and the palmar surface.
 - (B) Pain felt along the left thumb, index, and middle finger when placing the elbow on a table and flexing the wrist for 60 s.
 - (C) Pain felt along the left thumb, index, middle finger, and palmar surface when placing the elbow on a table and flexing the wrist for 60 s.
 - (D) Radial deviation of the wrist upon wrist flexion.
 - (E) Posterior and lateral forearm sensory deficit.
11. A 2-week-old female born at 39 weeks gestation to a 36-year-old G2P1 female via normal spontaneous vaginal delivery comes to her pediatrician for her 2-week well-baby exam. The birth was unremarkable, and the baby went home with her mother after 2 days. She received prenatal care starting at 10 weeks gestation and had a normal, healthy pregnancy with no issues. On physical exam, as the hip is gently adducted and posterior pressure is applied, there is a palpable clunk. Which of the following is the next step in management?
- (A) Reexamine at 1-month exam
 - (B) CT scan of the hips
 - (C) X-ray of the hips
 - (D) Reassurance
 - (E) Ultrasound of the hips
12. A 45-year-old woman presents with pain in her right hand for 2 days. She reports falling down and attempting to break her fall with an outstretched hand. Physical examination is significant only for pain in the anatomic snuffbox of her right hand. She has no motor weakness or sensory deficits. What is the most appropriate next step in management?
- (A) Radiograph of hand and if normal, recommend supportive care with follow-up.
 - (B) Radiograph of hand and if normal, recommend thumb spica cast with follow-up.
 - (C) Thumb spica cast without radiograph.
 - (D) Supportive care without radiograph.
 - (E) CT scan of hand.
13. An 88-year-old woman is brought in by ambulance after falling in her house. She complains of right hip pain. On physical exam, her temperature is 37.6 °C, blood pressure is 110/75 mmHg, pulse is 110/min, and respirations are 20/min. The leg appears externally rotated and shortened. X-ray shows femoral neck fracture. Which of the following is a complication of femoral neck fracture?
- (A) Avascular necrosis
 - (B) Lumbar radiculopathy
 - (C) Long-term loss of hip abduction
 - (D) Long-term loss of hip adduction
 - (E) Osteosarcoma

14. A 28-year-old man presents to the emergency department with an inability to move his right arm. After his initial workup and imaging is completed, he is found to have a posterior dislocation of the right shoulder. Which of the following are most commonly associated with this type of injury?
- (A) Fall on outstretched hand
 - (B) Weight lifting
 - (C) While walking dog, it suddenly tugs on leash
 - (D) Electrocution
 - (E) Surfing
15. A 35-year-old female telemarketer presents with complaints of pain in her right wrist for the past 6 months. She also reports having numbness in her right hand that occurs with wrist flexion or extension. For the past month, she has been receiving corticosteroid injections after her doctor diagnosed her with carpal tunnel syndrome (CTS). However, her pain has dramatically increased over the past week and has started to affect her job performance. Her mother has rheumatoid arthritis. Her hand appears to be swollen and is tender to palpation. She is scheduled for a synovial fluid aspiration. Which of the following findings in the aspirate would indicate surgical intervention?
- (A) Glucose of 90 mg/dL
 - (B) WBC of 200 cells/ μ L
 - (C) High abundance of rheumatoid factor
 - (D) Negatively birefringent crystals
 - (E) Thick yellow-green fluid
16. An 11-year-old boy presents to his pediatrician because his mother is concerned that he has been limping for the past 3 days. He states that he is limping because of a dull, aching pain in the right groin and thigh that extends down to his right knee. He has no history of preceding trauma. The pain is increased by physical activity. On physical exam, there is a shift of the torso over the affected hip with standing. Which of the following explains this physical exam finding?
- (A) Weakness in hip abduction
 - (B) Weakness in hip flexion
 - (C) Weakness in hip extension
 - (D) Weakness in knee extension
 - (E) Weakness in knee flexion
17. A 24-year-old woman presents to the emergency department with shoulder pain after a sports injury. She is found to have an anterior dislocation of the humeral head from the glenoid fossa. Which of the following is most likely to be injured in association with this type of dislocation?
- (A) Musculocutaneous nerve
 - (B) Radial nerve
 - (C) Axillary nerve
 - (D) Brachial arterial
 - (E) Medial clavicle
18. A young man is doing some woodworking in his backyard when the saw blade falls off the harness and onto his hand, severing his right thumb. After raising the right arm and applying direct pressure to control bleeding, which of the following is the best recommendation to keep his digit viable for potential replantation?
- (A) Immediately place the digit directly in a small bag filled with cold water.
 - (B) Immediately place the digit directly on top of ice.
 - (C) Remove any dirt from the digit first, and then place directly on top of ice.
 - (D) Remove any dirt from the digit first with a clean damp cloth, and then place digit directly in cup of cold water.
 - (E) Remove any dirt from the digit first, wrap in a clean damp cloth, put in a plastic bag, and then place bag directly in cup of cold water.

19. A 20-year-old college football player sustained a knee injury following a tackle. In the emergency department, his knee is very swollen, and a proper examination is not possible due to pain. Plain x-rays of the knee are negative. He is discharged home with a knee brace and crutches. During follow-up 2 weeks later, the pain and swelling are significantly improved. Which of the following findings would be most consistent with a tear to the posterior cruciate ligament (PCL)?
- (A) The lower leg sags on passive flexion of the knee at 90° while the patient is supine.
 - (B) The lower leg moves forward relative to the knee with forward traction.
 - (C) The foot moves laterally when the knee is pushed medially.
 - (D) The foot moves medially when the knee is pushed laterally.
 - (E) A clicking sensation is appreciated when the knee is flexed and the leg is rotated externally.
20. A 16-year-old boy arrives for his 1 month follow-up after straining his back and fracturing his tibia during a snowboarding accident. He has a long leg cast and uses crutches to get around. He reports that he lost the crutches given to him upon discharge but has been using an old pair that belonged to his older brother. His only complaint is a weak left hand that sometimes “falls” when he stretches out his arm. On physical exam, he has sensory deficits on the lateral dorsal side of his left hand. His leg is not bothering him and appears to be healing well. What is the most likely explanation for his upper extremity abnormalities?
- (A) Missed midshaft humerus fracture
 - (B) Radial nerve injury
 - (C) Long thoracic nerve injury
 - (D) Ulnar nerve injury
 - (E) Musculocutaneous nerve injury
21. A 25-year-old man arrives to the emergency department after a motor vehicle accident. After primary and secondary surveys are completed, he was found to have a right-sided pneumothorax, a fracture of the right clavicle, and a fracture of the left midshaft humerus. A bruit is heard over the right upper chest. What is the most appropriate next step after placing a chest tube and subsequent chest x-ray to confirm placement of the tube?
- (A) CT angiogram of the chest and arm
 - (B) Non-contrast CT of the shoulder and clavicle
 - (C) MRI study
 - (D) Nerve conduction test to assess for radial nerve injury
 - (E) Echocardiogram
22. A 28-year-old pregnant woman suffering from preeclampsia is being monitored in the hospital the night before her elective induction when she experiences a generalized seizure. After the successful delivery of a healthy baby boy the next morning, her doctor notices that she is unable to lift or externally rotate her right arm. An upper extremity anteroposterior radiograph is taken but does not reveal any abnormalities. What is the most appropriate next step in management?
- (A) Repeat radiographic studies of the upper extremity.
 - (B) MRI of the upper extremity.
 - (C) CT scan of the upper extremity.
 - (D) Operating room.
 - (E) Reassurance and observation.

Answers

✓ 1. Answer D

The patient is most likely exhibiting slipped capital femoral epiphysis (SCFE), which affects obese adolescent males. In SCFE, the femoral head separates from the neck and slips posteriorly, resulting in a limp and impaired internal rotation. Patients often present with knee pain, so a high index of suspicion is necessary to diagnose SCFE. The physical exam finding includes altered gait such that the patient takes a short step on the affected side to minimize weight-bearing due to pain and tenderness to palpation at the anterior hip. The diagnosis of SCFE is made with x-rays, which show the classic “ice cream slipping off the cone” suggesting posterior displacement of the femoral head. Obesity seems to be the strongest risk factor for SCFE, likely due to excessive mechanical stress on the physis (growth plate). Weight loss can be beneficial to the overall health of the child and will decrease the risk of SCFE in the contralateral hip but is not considered a definitive management intervention for SCFE (C). Treatment involves operative stabilization using pinning of the hip joint. Supportive therapy with rest and ibuprofen would be the appropriate treatment for transient synovitis (A). Aspiration of the synovial fluid along with appropriate antibiotic therapy would be the treatment for septic arthritis (B). Pavlik harness is used in the management of developmental dysplasia of the hip to keep the hip in a flexed and abducted position (E).

✓ 2. Answer E

This patient has a meniscal tear with a positive McMurray’s sign. This maneuver helps identify a meniscal tear and is positive if there is a palpable or audible snap occurring when extending the knee from a fully flexed position while applying tibial torsion. Meniscal tears can also present concurrently with other injuries. A medially directed blow to the lateral knee (valgus stress) results in the “unhappy triad”: medial meniscus tear, medial collateral ligament tear, and anterior cruciate ligament tear. Both ligamentous and meniscal tears can produce popping sounds during the injury, but ligamentous tears have rapid swelling occurring immediately, while meniscal tears have delayed swelling occurring the next day (A–B). Stress fractures do not typically occur in the patella following trauma (C). Instead, they occur more commonly in long bones (e.g., tibia) that are subjected to repeat stress or sudden increase in exercise. A patellar tendon displacement will present with a patient unable to resume weight-bearing, an indentation at the bottom of the kneecap, a proximally displaced patella, and hemarthrosis (D).

✓ 3. Answer C

The most common cause of superficial unilateral hip pain in the adult is inflammation of the trochanteric bursa. It is caused by friction of the gluteus medius tendon and the tensor fascia lata over the outer femur as a result of gait impairment, trauma, or infection. Untreated, the bursal wall thickens, fibroses, and gradually loses its ability to lubricate the outer hip. Patients may experience hip pain when they lay on the affected side or during external hip rotation (or resisted abduction). Hip osteoarthritis most commonly presents in patients over 40 years of age (A). The principal symptom associated with osteoarthritis is hip pain, which is localized in the groin and exacerbated by activity and relieved by rest. Meralgia paresthetica is compression of the lateral femoral cutaneous nerve. The nerve is susceptible to compression. The principle symptom is numbness and tingling and/or burning pain localized in the upper outer thigh (B). Osteonecrosis presents with groin pain (D). Hip fracture would present with severe pain, inability to bear weight, and intolerance to movement of the hip (E).

✓ 4. Answer B

Osteosarcomas are primary malignant tumors of the bone. The primary presenting symptom of osteosarcoma is localized pain that is typically present for an extended period of time and may be worse at night. On physical exam, there may be a soft tissue

mass, which is frequently large and tender to palpation. Osteosarcomas have a predilection for the metaphysis of long bones and are most commonly found in the distal femur, proximal tibia, and proximal humerus. The first diagnostic test to work up bone pain is an x-ray, which shows periosteal bone formation, lifting of the cortex, and the classic “sunburst pattern.” Ewing’s sarcoma presents in a similar manner, but the radiographic appearance is described as “onion peel” appearance due to the periosteum being displaced by the underlying tumor causing the characteristic periosteal reaction that produces layers of reactive bone (A). Growing pains present with recurrent, self-limited extremity pain. In contrast to bone pain, which is unilateral, growing pains are bilateral. Osteomyelitis presents with localized pain, fever, and leukocytosis of acute onset (C). Osteochondroma (exostosis) is a benign, firm solitary bone tumor commonly occurring in teenage males (D). Osteoid osteoma is a benign, painful growth of the diaphysis in long bones (e.g., femur, tibia) of teenage males most commonly (E). The pain is characteristically worse at night but better with aspirin. On plain film, there is a central radiolucency surrounded by a sclerotic rim.

✓ 5. Answer A

A medially directed blow to the lateral knee (valgus stress) results in the “unhappy triad”: medial meniscus tear, medial collateral ligament tear, and anterior cruciate ligament tear. The most appropriate test in order to determine soft tissue injuries of the knee is MRI. This study is the most appropriate study to investigate soft tissue injuries of the knee. It is superior to CT as it is better able to demonstrate ligamentous and meniscal lesions (B). However, its use should only be limited for patients in which the diagnosis is in question. MRI is no more accurate than the physical examination of an experienced clinician, and so referral to a sport medicine physician or orthopedic surgeon should be considered prior to ordering MRI. Radiographic studies are not typically helpful or performed for sports injuries, but they are useful in traumatic knee injuries (C). Arthroscopy can be used for diagnostic purposes if the MRI is equivocal or if it is abnormal and warrants subsequent surgical intervention (D). Although nerve injuries may accompany knee injuries, nerve conduction studies are not typically ordered in workup of soft tissue injuries of the knee (E).

✓ 6. Answer C

This surgeon most likely has a tibial stress fracture. This injury is common in patients that have a sudden change in physical activity and/or long periods of standing. His fatigue could be explained by jet lag and returning from an intense medical mission trip. Stress fractures present with pain upon palpation and some surrounding edema of the skin. After physical exam, the first step in evaluating a possible stress fracture is a plain film. It is unlikely to show up on plain films, and so clinical judgment should dictate whether to start appropriate therapy. Most patients with stress fractures could be managed with supportive therapy: reduce activity to the level of pain-free functioning, over-the-counter analgesics, stretching exercises, and/or biomechanical stress-relieving measures. MTSS (A), also known as shin splints, is a common cause of exertional leg pain in athletes. Patients with MTSS complain of vague, diffuse pain (compared to focal in stress fracture) of the lower extremity, along the middle-distal tibia associated with exertion. Conversely, patients with exertional compartment syndrome will present with exercise-induced pain in the *lower* legs that quickly disappears with rest (C). This occurs in college athletes and long-distance runners. The exact cause is not well understood, but several leading theories exist. During exercise, blood flow to the muscle increases, and in patients with constricted compartments (e.g., hypertrophic leg muscles in college athletes), this increased blood flow may result in increased pressures that can cause pain. Osgood-Schlatter disease occurs in adolescence during a time when there is increased strain on the tibial tubercle (from repetitive quadriceps contraction via the patellar tendon) (B). Exertional pain at the knees that resolves with rest is the most common complaint. Osteomyelitis is a possibility and can be ruled out with a serum ESR (E). However, a stress fracture is far more likely.

✓ 7. Answer A

This patient has suppurative tenosynovitis with the characteristic four cardinal signs (*Kanavel signs*): flexor tendon sheath tenderness, fusiform swelling (sausage-shaped digits), pain with passive extension, and a semi-flexed posture of the involved digit. It is a closed space infection, and some may be associated with past penetrating injuries to the hand. The most likely organism is *Eikenella corrodens* which is often associated with human bites (e.g., punch in the mouth/face). *Pasteurella multocida* can also cause suppurative tenosynovitis but is associated with cat scratches (D). Management of suppurative tenosynovitis involves mid-axial longitudinal incision and drainage. Gout is a crystal-induced arthropathy that commonly first presents in the big toe (podagra) (B). Dupuytren's contracture is associated with diabetes, smoking, and alcohol abuse (C). It presents with contractures in the fourth and fifth digits secondary to proliferation of the palmar fascia of the hand. Felon is a term used to describe infection in the terminal joint space of the finger (E).

✓ 8. Answer E

This patient is most likely exhibiting avascular necrosis of the proximal femoral head (hip) (Legg-Calvé-Perthes disease). Avascular necrosis of the hip typically presents as hip pain, anterior thigh pain, or referred knee pain as well as a limp (which may be painless) in children between the ages of 4 and 10 years with a male-to-female ratio of 4:1. Often, children are unable to localize hip pain and may state they have knee pain, confusing the picture. Avascular necrosis is usually idiopathic but may occur secondary to an underlying condition such as glucocorticoid use. Clinical features include insidious onset of hip pain and limp. Physical exam shows limitation in internal rotation of the hip. Initial radiographs are often normal. Later in the course, radiographs show fragmentation of the femoral head. Septic arthritis presents with acute onset of refusal to bear weight, pain, swelling, warmth, with fever, and leukocytosis (A). Osteomyelitis is spread hematogenously in children and affects the metaphysis of long bones. It presents with localized pain and fever along with leukocytosis and elevated ESR and CRP (B). SCFE affects obese adolescent males and presents with altered gait (C). Torn ACL affects adolescent girls more often and would present with a history of trauma, swelling at the knee joint, and increased anterior translation of the knee on physical exam (D).

✓ 9. Answer A

A rotator cuff injury presents with pain along the shoulder and weakness of abduction at the shoulder. The *drop arm test* is used to evaluate for a tear in the supraspinatus muscle, a rotator cuff injury. This is performed by passively abducting the patient's shoulders to 90° and flexing to 30° while asking the patient to point his thumbs down. The test is positive if the patient is unable to keep arms elevated after the examiner releases or if the patient is unable to smoothly lower the arms. The supraspinatus is part of the rotator cuff, along with the infraspinatus, teres minor, and the subscapularis muscles (B–C). MRI can help confirm rotator cuff injury. Teres major is not part of the rotator cuff (D).

✓ 10. Answer B

CTS is a clinical diagnosis and can be supported with a positive Tinel's and/or Phalen's sign. Tinel's sign is elicited by gently percussing over the median nerve at the carpal tunnel. A positive sign is present if the patient described an electrical shock sensation in the median nerve distribution (A). Phalen's test is performed by having the patient place their elbow on a table and flexing the wrist for 60 s. The test is considered positive if the patient reports paresthesias in the median nerve distribution. The median nerve controls sensation to the thumb, index, middle, and half of the ring finger. Palmar sensation is not affected by CTS because the superficial palmar cutaneous branch of the median nerve passes superficially to the carpal tunnel (C). Radial deviation of the wrist upon wrist flexion would be expected with ulnar nerve injuries (D). Posterior and lateral forearm sensory deficit would be expected with musculocutaneous nerve injuries (E).

✓ 11. Answer E

This infant is exhibiting developmental dysplasia of the hip (DDH), which describes a spectrum of conditions that cause the abnormal development of the acetabulum and proximal femur in infants and children. In young infants, it is important to routinely evaluate for DDH using the Barlow and Ortolani maneuvers, which are physical examination techniques to detect hip instability that use adduction and posterior pressure to feel for dislocatability and abduction to feel for reducibility, respectively. If a sensation of a “clunk” is found on physical exam, further workup is warranted including immediate referral to an orthopedic surgeon. Reassurance and reexamination would be inappropriate (A, D). Ultrasound is the primary imaging technique for assessing abnormalities of the hip until 4–6 months of age because plain x-rays have limited value in the first 6 months of life when the femoral head and acetabulum are not yet ossified (C). CT scan is not useful in the diagnosis of DDH (B). Treatment involves splinting, casting, and/or surgery.

✓ 12. Answer B

This patient has a classic history for a scaphoid fracture. This injury usually occurs in patients that fall on an outstretched hand with the wrist extended and presents with tenderness in the anatomic snuffbox. Plain films are typically *normal* and unrevealing of scaphoid fractures if taken soon after injury. If clinical suspicion is high, all patients should be immobilized with a thumb spica cast and reimaged 7–10 days later. Supportive care with or without radiographs is not appropriate for classic cases of scaphoid fractures (A, D). Radiographs are recommended for all patients to look for more serious injuries that may be associated with scaphoid fractures (C). If patients are found to have signs suggestive of wide displacement or ligament disruption, then more advanced imaging studies should be done (E). A displaced scaphoid fracture should be considered for surgical intervention as this has a high risk of osteonecrosis and non-union.

✓ 13. Answer A

Femoral neck fractures are most commonly seen in elderly patients after a fall. Women sustain hip fractures more often due to their higher rates of osteoporosis. Femoral neck fractures have a relatively high rate of complications compared with extracapsular hip fractures because they are intracapsular. The risk for compromise in the blood supply to the femoral neck as a result of the fracture increases the risk of complications, in particular avascular necrosis (AVN). Long-term loss of hip abduction/adduction is prevented with physical rehabilitation (C–D). Osteosarcoma and lumbar radiculopathy are not complications of a femoral neck fracture (B, E).

✓ 14. Answer D

An anterior dislocation of the shoulder joint is the *most common form* of shoulder dislocation. Posterior dislocations are rare and occur most often in patients that have had generalized seizures or have been electrocuted. Patients with posterior shoulder dislocations will present with an adducted arm that is *internally rotated*, while anterior dislocations present with an *externally rotated arm*. Sport injuries are more likely to cause anterior dislocations of the shoulder joint (A). Similarly, a sudden forceful subluxation of the shoulder that may occur from a dog tugging at the chain can lead to an anterior shoulder dislocation (C). Weight lifters are at increased risk for thoracic outlet obstruction which presents with symptoms caused by obstruction of nerves and vessels passing from the thoracocervical region to the axilla (e.g., upper extremity paresthesia, weakness, and edema) (B). Swimmers and surfers are more likely to present with symptoms consistent with *impingement syndrome* secondary to rotator cuff tendinopathy from repetitive paddling (E). This occurs when a nerve or soft tissue is compressed between the humeral head and acromion.

✓ 15. Answer E

This patient was recently diagnosed with CTS but presents with an acute episode of septic arthritis which can be managed with surgical washout. Any patient with an inflammatory condition that has a sudden and dramatic *increase in pain* should always

be suspected of this and appropriately worked up with synovial fluid analysis. Surgical washout would be indicated in this patient if she had thick purulent (e.g., yellow-green) material. Furthermore, she was getting local injections of corticosteroid which is a relative indication for surgical washout given the potential immunocompromised state. Glucose <25 mg/dL and WBC >2000 cells/ μ L (often $>50,000$ cells/ μ L) would be suggestive of septic arthritis (A, B). Rheumatoid factor found in synovial fluid would be supportive of a diagnosis of rheumatoid arthritis, which is treated systemically (C). Finally, negative birefringent crystals are the hallmark of gouty arthritis, which is not treated surgically (D).

✓ 16. Answer A

The patient is most likely exhibiting slipped capital femoral epiphysis (SCFE), which affects obese adolescent males. The physical exam finding being described is the *Trendelenburg sign*, which is a shift of the torso over the affected hip due to gluteus muscle weakness as well as weakness in hip abduction (B–E). In addition, physical exam may reveal that the patient's gait is altered with the patient taking a short step on the affected side to minimize weight-bearing due to pain. The anterior hip may be tender to palpation. Despite a complaint of pain in the knee area, the knee examination is normal.

✓ 17. Answer C

Anterior dislocations of the humeral head increase the patient's risk for concurrent axillary nerve injury. All these patients should be evaluated for axillary nerve damage. This can cause paralysis of the deltoid and teres minor muscles as well as a loss of sensation over the upper lateral arm. Musculocutaneous nerve injuries are not common in patients that have sports injuries (A). These patients will present with paralysis or weakness in the biceps and brachialis muscles. Radial nerve injuries are associated with fractures of the humeral midshaft (B). Brachial arterial injury is a concern for patients with a supracondylar fracture (D). Medial clavicle injury is difficult to attain and is not expected to occur concurrently in patients that have an anterior dislocation of the humeral head (E).

✓ 18. Answer E

Severed body parts can sometimes be reattached if the proper steps to ensure tissue viability are taken. There are new and promising replantation techniques available. However, nerve regeneration continues to be a major limiting factor. Young patients with sharp amputations and no crush injury are the best candidates for replantation. The best recommendation to keep an amputated digit viable is to remove any dirt from the digit first, wrap it in a clean damp cloth (moistened saline-soaked gauze), put it in a plastic bag, and then place the bag directly in a cup of cold water. This will ensure viability for up to 18 h.

✓ 19. Answer A

The most consistent finding with a tear in the PCL would be a lower leg that sags on passive flexion of the knee at 90° while the patient is supine. An anterior cruciate ligament (ACL) tear would present with the lower leg moving forward relative to the knee with forward traction (B). A tear in the medial collateral ligament (MCL) would present with a foot that moves laterally when the knee is pushed medially (C). A tear in the lateral collateral ligament (LCL) would present with a foot moving medially when the knee is pushed laterally (D). A clicking sensation that is heard when the knee is flexed and the leg is rotated externally is known as McMurray's sign and is positive with a meniscal tear (E).

✓ 20. Answer B

Radial nerve injuries present with wrist drop and sensory loss to the posterior arm and lateral dorsal aspect of the hand. This most commonly occurs in patients that have had fractures to the humeral midshaft and those that use improperly fitted crutches. This

patient is using crutches that belonged to his older brother and is likely responsible for his upper extremity abnormalities. If a fracture in the midshaft of the humerus did not present clinically during the time of his snowboarding accident, it is unlikely to cause significant problems a month later (A). Long thoracic nerve injuries can occur in women with breast cancer that receive axillary lymphadenectomy (C). This will present with scapular winging. Ulnar nerve injury presents with sensory changes in the 4th and 5th digits (D). Musculocutaneous nerve injuries will present with paralysis or weakness in the biceps and brachialis muscles (E).

✓ 21. Answer A

Most clavicle fractures can be managed conservatively with a shoulder string or brace for 6–8 weeks. However, all patients with fractures to the clavicle should receive a careful neurovascular examination since these patients are at risk for brachial plexus and axillary/subclavian arterial injury. CT angiogram is not routinely necessary but is indicated in the presence of a thrill or bruit around the clavicle, diminished or absent radial/brachial pulse, fracture of the first rib, large hematoma in the supraclavicular region, or mediastinum widening on plain films. A CT scan of the shoulder can help estimate the intra-articular extension of the clavicular fracture in the acromioclavicular joint; however, contrast should be given to look for arterial injury (B). MRI can help diagnose coexistent injuries of rotator cuff or intra-articular disk of the acromioclavicular joint (C). Although radial nerve injuries can commonly accompany midshaft humeral fractures, they are more likely to present clinically with wrist drop and sensory loss to the posterior arm and lateral dorsal aspect of the hand. Nerve conduction studies are typically not needed, particularly when there are no physical exam findings suggestive of nerve damage (D). Blunt cardiac injury can occur in patients following motor vehicle accident. This should be considered if the patient presents with chest pain and/or hemodynamic instability. Given his age, the bruit heard in his chest is unlikely to be related to underlying cardiovascular disease. For these reasons, an echocardiogram is not indicated (E).

✓ 22. Answer A

Pregnant patients with preeclampsia or eclampsia that present with an inability to move the arm following a seizure are most likely suffering from a posterior shoulder dislocation. These are rare and occur most often in patients that have had generalized seizures or have been electrocuted. Pregnant patients suffering from eclampsia are also at risk because of its association with seizures. Regular anteroposterior radiographs will often miss the diagnosis, and so patients suspected of having a posterior dislocation should receive *axillary and lateral view* radiographs. The axillary view is essential for diagnosis as it can help estimate the size of the defect in the humeral head. If radiographs are equivocal, a CT scan can be ordered next (C). MRI is considered for older patients with shoulder dislocation as they are more likely to have concurrent rotator cuff injury (B). Reassurance is not appropriate for shoulder dislocation (E). Most patients are able to manage a shoulder dislocation with nonoperative therapy (D).

Pediatric

Steven L. Lee

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Full-Term Male Infant with Respiratory Distress

Veronica F. Sullins, Rivfka Shenoy, and Steven L. Lee

Case Study

A full-term male infant becomes cyanotic immediately after birth. His mother states she had no access to prenatal care. Her pregnancy was otherwise uncomplicated. On examination, the newborn is tachypneic and tachycardic, and his oxygen saturation is 75%. He is grunting and has supracostal retractions. He has a barrel-shaped chest with decreased breath sounds on the left side. His abdomen is scaphoid, and his heartbeat is displaced to the right. The amniotic fluid is clear.

Diagnosis

What Is the Differential Diagnosis of Surgical Causes of Neonatal Respiratory Distress

Table 34.1

Diagnosis	Comments
Choanal atresia	Neonates are obligate nasal breathers (nasogastric tube cannot be placed)
Congenital diaphragmatic hernia	Loops of intestine (left) above the diaphragm on CXR
Pulmonary cystic lesions	Cystic lesion seen on CXR includes congenital cystic adenomatoid malformation (CCAM), bronchopulmonary sequestration, congenital lobar emphysema (CLE)
Esophageal atresia +/- tracheoesophageal fistula (TEF)	Scaphoid abdomen, excessive salivation, +/- stomach bubble, +/- vomiting, orogastric tube curled in the upper esophagus
Mediastinal lesions	Diagnosed incidentally or patient develops infected cyst, secondary mass effects if large enough; includes bronchogenic cysts and mediastinal masses
Pneumothorax	Decreased breath sounds on affected side with collapsed lung on CXR

CXR chest X-ray

What Is the Most Likely Diagnosis?

Congenital diaphragmatic hernia (CDH). The constellation of severe respiratory distress in a full-term neonate with decreased breath sounds on the left and a scaphoid abdomen should be highly suspicious for this condition, and a chest radiograph will confirm the diagnosis (Fig. 34.1). A scaphoid abdomen describes a sunken abdominal wall with a concave, rather than normal convex shape. It implies a smaller volume of abdominal contents than normal and may also be seen in cases of proximal bowel obstruction and



Fig. 34.1 Chest radiograph of an infant with CDH

malnutrition. In CDH, the abdomen is scaphoid because the intra-abdominal contents have herniated into the chest.

What Are the Most Common Causes of Neonatal Respiratory Distress?

It is important to note that the most common causes of neonatal respiratory distress are not surgical. A benign condition, *transient tachypnea of the newborn* accounts for more than 40% of cases of neonatal respiratory distress. It occurs when residual pulmonary fluid remains in the lung tissue after delivery. Chest radiograph typically shows diffuse parenchymal infiltrates and a “wet silhouette” around the heart. Symptoms may last from a few hours to multiple days. In premature babies, the most common cause of respiratory distress is hyaline membrane disease or respiratory distress syndrome. This is due to a decrease in surfactant production by type-II alveolar cells. Homogenous opaque infiltrates with air bronchograms are typically seen on chest radiography. Another common medical cause in term or post-term infants is meconium aspiration syndrome, and meconium-stained amniotic fluid is seen. Although less common, persistent pulmonary hypertension, pneumonia, and non-pulmonary etiologies (i.e., cardiac, renal) are also in the differential diagnosis of newborn respiratory distress.

History and Physical

What Is the Significance of the Supracostal Retractions and Grunting?

Grunting and costal retractions (subcostal, intercostal, or supracostal) indicate ongoing or impending severe respiratory distress and should alert the clinician to impending cardiorespiratory collapse. Patients of all ages who exhibit signs of severe respiratory compromise should be intubated and placed on mechanical ventilation.

What Information Does the Pulmonary Examination Provide?

Decreased or absent breath sounds in a newborn may be due to abnormal lung development as seen with pulmonary agenesis or bronchial atresia. Alternately, there may be a pneumothorax or a space-occupying lesion as in CDH, teratoma, bronchopulmonary sequestration, and bronchogenic cyst.

Why Is the Heartbeat Displaced?

A displaced heartbeat occurs when a space-occupying lesion has enough volume to shift the mediastinum toward the contralateral side. Frequently a barrel-shaped chest will accompany this finding.

Why Is the Absence of Prenatal Care Important?

The majority of CDH is diagnosed prenatally by maternal ultrasound examination or, in some cases, MRI. CDH can be successfully diagnosed as early as 15 weeks gestation; however, most are diagnosed by 24 weeks. Prenatal ultrasound findings of bowel loops seen in the thoracic cavity or shift of the heart and mediastinum toward the contralateral side are diagnostic of CDH. Therefore, the absence of prenatal care should alert the physician of the possibility of a malformation that is typically diagnosed in utero.

Pathophysiology

What Is Thought to Be the Etiology of CDH?

CDH results from failure of the septum transversum to completely divide the pleural and coelomic (later becomes the peritoneal) cavities during fetal development. Fusion of this diaphragmatic precursor is usually completed posteriorly by the 12th week of gestation. Herniation of intra-abdominal contents occurs during a critical period of lung development when the pulmonary arteries and bronchi are branching. Pulmonary hypoplasia results from decreased pulmonary mass and bronchiolar branching as well as dysfunctional surfactant production.

Watch Out

In CDH, pulmonary hypoplasia occurs in *both* lungs.

Are There Different Type of CDHs?

Approximately 85% of CDH occurs on the left side, 10% on the right side, and <5% bilaterally. The most common variant

is a posterolateral defect, known as a Bochdalek hernia. Anteromedial defects, or Morgagni hernias, are much rarer and occur in a para- or retrosternal location. Most Morgagni hernias are asymptomatic and less severe and do not therefore present with neonatal respiratory compromise. They are more likely to present later in childhood or early adulthood with gastrointestinal symptoms or obstruction.

How Is Fetal Blood Shunted Away from Pulmonary Circulation In Utero?

In utero, high pressure in the fetal pulmonary vasculature causes blood to flow away from pulmonary circulation and into systemic circulation. This is achieved through two fetal shunts. Most blood entering the right atrium is shunted through the foramen ovale into the left atrium, away from the right ventricle and lungs. Blood pumped into the pulmonary arteries from the right ventricle is shunted away from the pulmonary arterial tree and the lungs into systemic circulation through the ductus arteriosus, which connects the main pulmonary artery to the aortic arch and is just distal to the left subclavian artery.

What Are the Changes That Occur During Childbirth That Allow the Neonate to Transition to Breathing Air?

When a newborn takes the first breath of air, the pulmonary vascular bed transitions from a high resistance to a low resistance system leading to more oxygenated blood reaching the left atrium, which increases left atrial pressure relative to the right atrium. Blood flow then reverses across the foramen ovale, which subsequently closes. The increase in oxygen concentration in the blood causes a local decrease in prostaglandins and subsequent closure of the ductus arteriosus. Thus, both shunts close leading to the standard adult circulation.

How Is This Transition Affected By CDH?

Herniation of the abdominal contents into the thoracic cavity causes pulmonary hypoplasia on the ipsilateral side and to the contralateral side. The mediastinum is shifted, thereby compressing the contralateral lung. Pulmonary hypoplasia combined with the muscular hyperplasia of the pulmonary arterial tree causes high resistance in the pulmonary arterial bed that does not reverse with the infant's first breath. The resultant hypoxemia, acidosis, and hypotension cause pulmonary vasoconstriction, worsening the patient's pulmonary hypertension. In summary, pulmonary hypertension results in decreased pulmonary blood flow and hypoxia, and pulmonary hypoplasia results in decreased gas exchange and carbon dioxide retention.

Are There Associated Anomalies?

Approximately 50–60% of affected infants have isolated CDH. CDH is considered complex when it exists in conjunction with other associated anomalies including structural malformations, chromosomal abnormalities, and single-gene mutations (■ Table 34.2).

Workup

What Is the Best Initial Diagnostic Test?

Surgical causes for newborn respiratory distress can be ruled out by placement of an orogastric (OG) tube followed by chest radiograph. This may confirm some diagnoses and rule out others. In meconium aspiration syndrome or pneumonia, chest X-ray may show patchy atelectasis or consolidation. An OG tube curled in the upper esophagus may be due to esophageal atresia with or without a TEF. In CDH, if the lesion is on the left side, air- or fluid-filled bowel loops may be seen above the diaphragm. If the lesion is on the right side, the liver may be seen as a soft tissue mass in the thoracic cavity with absence of the normally seen intra-abdominal liver shadow. The heart and other mediastinal structures are

shifted to the contralateral side, compressing the lung. If a feeding tube is placed prior to imaging, it may be seen within the thoracic cavity. Similarly, there will be abnormal lung fields in primary pulmonary lesions, such as CCAM, CLE, pulmonary atresia, bronchogenic cysts, and pulmonary agenesis. Choanal atresia can be diagnosed by inability to pass a nasogastric (NG) tube. A diagnostic algorithm for surgical causes of newborn respiratory distress is shown in ■ Fig. 34.2.

Management

What Is the Most Important Step in Clinical Management?

Newborns with respiratory distress should be immediately intubated. An OG tube should be placed to low continuous suction to decompress the stomach and proximal small bowel and to help available lung tissue expand further. To minimize injury to remaining lung tissue, low pressure ventilation settings should be used. Neonatal ICU admission and blood pressure support should be initiated as necessary.

What Type of Ventilation Is Recommended? What if the Patient Cannot Be Adequately Oxygenated and/or Ventilated?

If standard mechanical ventilation is inadequate, high-frequency oscillatory ventilation is often utilized as it permits lower airway pressures and less lung damage. If this is unsuccessful, the patient is placed on extracorporeal membrane oxygenation (ECMO). With standard ECMO a cannula is placed into the jugular vein and another into the carotid artery.

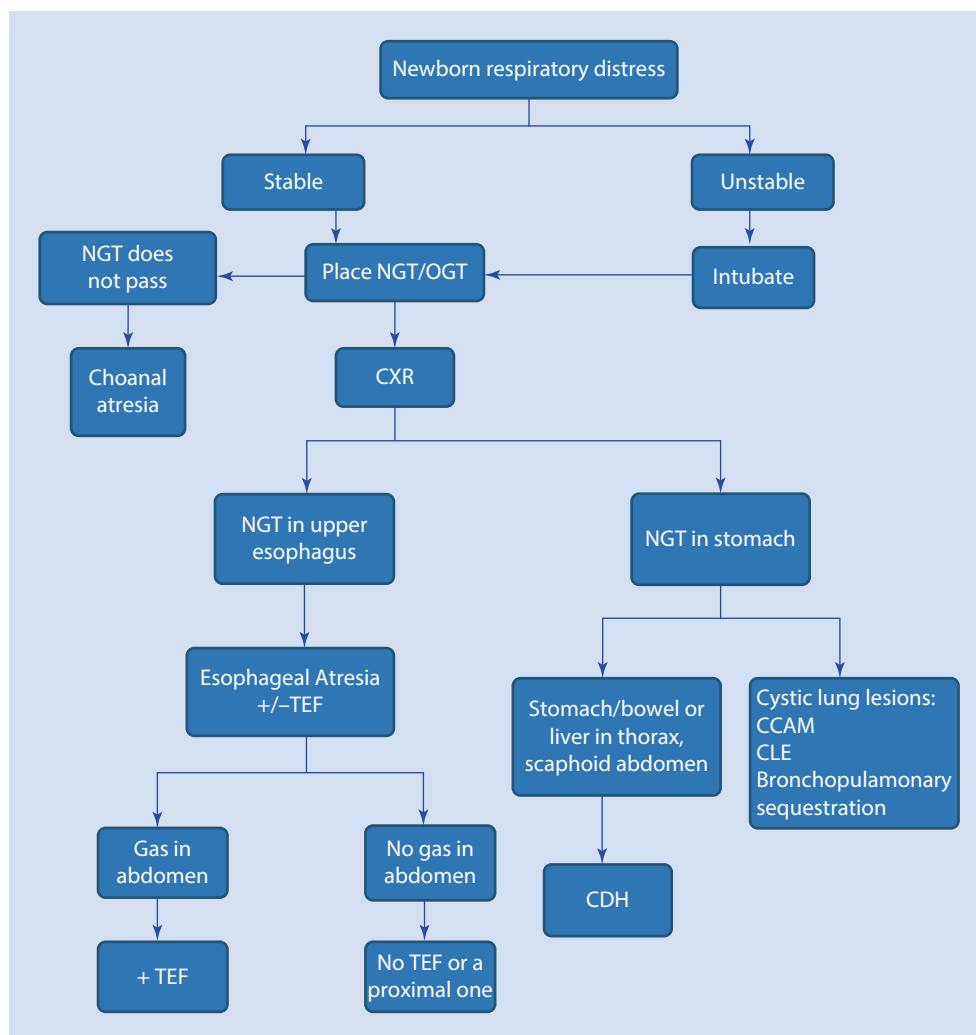
What Is the Timing of Surgical Repair?

In the early era of surgical management of patients with CDH, surgery was performed immediately to repair the diaphragmatic defect. However, overall survival did not improve beyond 50%. The goal in management of CDH is supporting lung function because survival is directly related to the degree of pulmonary hypoplasia and pulmonary hypertension. Repairing the diaphragm will not improve pulmonary function. Patients with mild symptoms requiring minimal support likely have little or no pulmonary hypertension and may undergo surgical repair after just 48–72 hours. However, in most patients, the timing of surgery is *generally delayed*. It is important to provide cardiopulmonary support and avoid lung injury while awaiting lung maturation and reversal of pulmonary hypertension. In most cases time will improve lung function.

■ Table 34.2 Most common anomalies associated with CDH

Associated anomalies	Incidence
<i>Malrotation or nonrotation</i>	60–100%
<i>Cardiovascular</i>	63%
VSD/ASD	
Hypoplastic left heart	
<i>Genitourinary</i>	18–23%
Undescended or ectopic testes	
Ectopic or horse shoe kidney	
<i>Limb</i>	10–16%
Polydactyly	
Syndactyly	
<i>Central nervous system</i>	10–14%
Neural tube defects	
Hydrocephalus	
<i>Chromosomal abnormality</i>	10%
Trisomy 13, 18, or 21	
Single-gene/chromosome defect	
VSD ventricular septal defect, ASD atrial septal defect	

Fig. 34.2 Diagnostic algorithm for surgical causes of neonatal respiratory distress



Watch Out

Associated anomalies are common, and therefore an appropriate family history, examination, and workup with *echocardiogram*, limb radiographs, and renal and cranial ultrasounds are required prior to definitive surgical repair of the diaphragmatic defect.

herniated stomach/intestines with additional air. In addition, any delay in securing an airway may worsen hypoxia and acidosis, thereby increasing the risk of persistent pulmonary hypertension.

Area Where You Can Get in Trouble

Initial Intubation

The infant should be intubated as quickly as possible. Every effort should be made to avoid blow-by oxygen or bag-mask ventilation prior to endotracheal intubation as these can worsen lung compression and mediastinal shift by filling the

Area of Controversy

Type of Repair: Open Versus Minimally Invasive Surgery (MIS)

Recently, with improvements in minimally invasive surgery (MIS) techniques and technology, CDH repairs have been successfully performed thoracoscopically with encouraging reports of less pain, earlier recovery, and shorter length of hospitalization. However, there remain some concerns over hernia recurrence with the MIS technique. To date, most

evidence is based on retrospective review, and selection bias limits comparative data. Although no consensus currently exists, it has been suggested that the MIS approach be reserved for stable patients with isolated CDH (no additional anomalies), delayed presentation, and small diaphragmatic defects (not requiring patch repair).

Prognosis

What Is the Prognosis for CDH? What Are the Factors Affecting Prognosis?

Overall mortality has improved since the development of extracorporeal membrane oxygenation (ECMO) and surgical repair with current survival rates between 60% and 80%. Mortality is directly related to the degree of pulmonary hypoplasia and pulmonary hypertension as well as the presence of congenital anomalies.

Summary of Essentials

History, Physical Examination, and Diagnosis

- The most common causes of newborn respiratory distress are not surgical.
- Grunting and costal retractions and abnormal vital signs indicate severe respiratory compromise.
- In stable patients, placement of an OG/NG tube followed by chest radiograph will confirm or rule out common surgical diagnoses.
- In a newborn, severe respiratory distress with absent breath sounds and scaphoid abdomen suggests CDH and diagnosis can be confirmed with CXR.
- CDH is typically diagnosed in utero by prenatal ultrasound.

Etiology/Pathophysiology

- The majority occurs on the left side and the most common defect is posterolateral or Bochdalek hernia.
- Herniation of abdominal contents results in bilateral pulmonary hypoplasia.
- Pulmonary hypertension → decreased pulmonary blood flow and hypoxia; pulmonary hypoplasia → decreased gas exchange and carbon dioxide retention.
- Common associated anomalies: chromosomal defects, rotational, cardiac (VSD/ASD), central nervous system, limb, and genitourinary defects.
- Mortality directly related to degree of pulmonary hypoplasia and pulmonary hypertension and presence of congenital anomalies.

Management

- Immediate intubation with ventilator support if signs of respiratory distress.
- Survival directly related to the degree of pulmonary hypoplasia and pulmonary hypertension.
- Delay surgery to allow lungs to mature and for pulmonary hypertension to improve or reverse.
- Evaluate for other anomalies prior to surgery.

Suggested Reading

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Infant with Bilious Emesis

Rivfka Shenoy, Veronica F. Sullins, and Steven L. Lee

Case Study

A 7-month-old male infant presents with two episodes of green emesis, lethargy, oliguria, and decreased stool output. The mother states he was a full-term baby with no prior illnesses or surgery. He fed normally for months until the day prior to presentation. His last normal, non-bloody bowel movement was 24 hours ago. His heart rate is slightly elevated and he is normotensive and afebrile. He is lethargic but otherwise has a normal physical examination. His abdomen is soft, nontender, and nondistended.

Diagnosis

What Is the Differential Diagnosis for Bilious Emesis in an Infant?

Table 35.1

Diagnosis	Specific findings
<i>Adhesions</i>	Prior abdominal surgery, dilated loops of bowel with transition point to decompressed bowel on contrast study
<i>Enteric duplication cyst</i>	Fluid-filled structure not contiguous with stomach or small bowel on MRI/US
<i>Gastroenteritis</i>	History of fever, diarrhea, initial nonbilious emesis, diagnosis of exclusion
<i>Hirschsprung's disease</i>	Transition zone (caliber change) on contrast enema, absence of ganglion cells with hypertrophied nerve trunks on rectal biopsy
<i>Ileus secondary to other medical disease</i>	Metabolic derangements, electrolyte abnormalities, sepsis, multiple etiologies
<i>Incarcerated inguinal hernia</i>	Inguinal hernia with evidence of incarceration on physical exam
<i>Intussusception</i>	Target sign on US, possible preceding viral upper respiratory illness, "currant-jelly" stool
<i>Malrotation with midgut volvulus</i>	"Corkscrew" appearance of duodenum on contrast UGI, misplaced ligament of Treitz

MRI magnetic resonance imaging, US ultrasound, UGI upper gastrointestinal study

How Does Age Affect the Differential Diagnosis of Bilious Emesis?

Table 35.2

<i>All ages^a</i>	Adhesions
	Hirschsprung's disease
	Incarcerated inguinal hernia
	Malrotation with midgut volvulus
<i>Neonate (0–1 month)</i>	Annular pancreas
	Duodenal atresia
	Imperforate anus
	Jejunioileal/colonic atresia
	Meconium ileus/plug
	Necrotizing enterocolitis
<i>Infant (1–24 months)</i>	Intussusception
<i>Child (2–12 years)</i>	Ileus secondary to appendicitis
	Intussusception

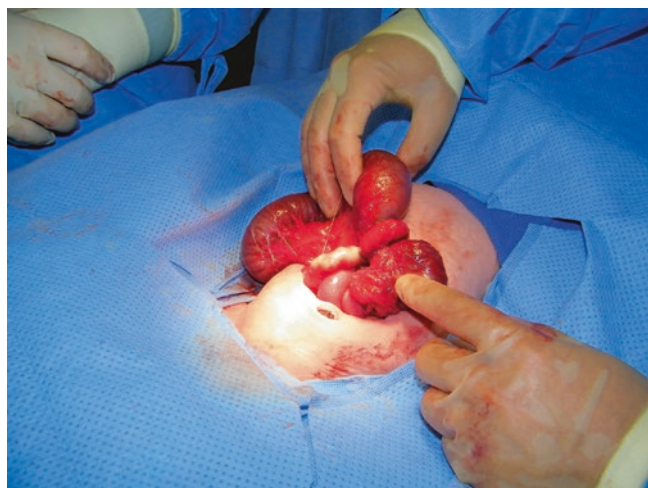
^aIn all ages, underlying sepsis or metabolic derangements may lead to ileus and bilious vomiting

What Is the Diagnosis?

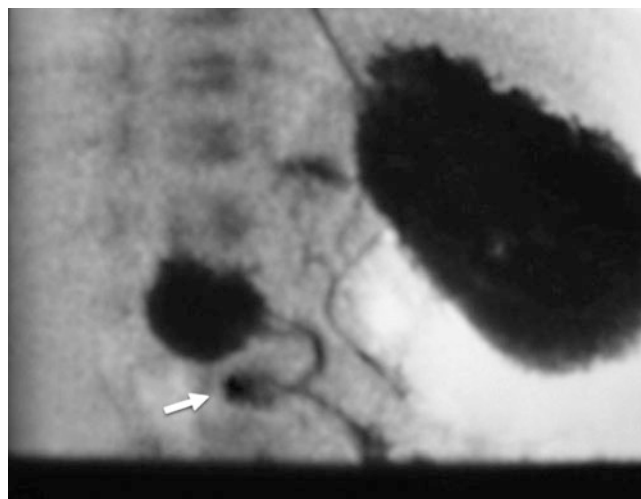
Malrotation with midgut volvulus (■ Fig. 35.1) should always be suspected in an infant or child with bilious vomiting and abdominal pain. While over half of children with malrotation present with volvulus (the twisting of the small bowel around its mesentery leading to intestinal ischemia) before 1 month of age, one-third present between 1 and 12 months.

Watch Out

Malrotation with midgut volvulus may present with either bilious or nonbilious vomiting depending on where the obstruction occurs. All cases of suspected duodenal obstruction should be evaluated for malrotation with midgut volvulus.



■ Fig. 35.1 Photograph of malrotation with midgut volvulus



■ Fig. 35.2 UGI contrast study with small bowel follow through

History and Physical

Why Is It Important to Distinguish Between Bilious and Nonbilious Vomiting in an Infant?

Bilious emesis is any green or yellow emesis and is essential diagnostic information because bilious emesis is most likely due to a surgically correctable lesion until proven otherwise. Obstructive processes proximal to the pylorus always cause nonbilious emesis (such as pyloric stenosis), whereas bilious emesis implies a patent pylorus with obstruction distal to the ampulla of Vater. Distinguishing between proximal and distal causes of obstruction will determine what type of diagnostic study to perform.

Workup

What Is the First Imaging Study to Obtain?

Given that the patient is hemodynamically stable, the first study to obtain is a plain abdominal radiograph. While plain radiographs are rarely diagnostic, they may reveal free air under the diaphragm, consistent with bowel perforation. If there is evidence of perforation, no additional studies are needed, and the patient should be taken to the operating room for urgent laparotomy. The presence and location of bowel gas on plain radiographs may also help determine whether the patient has a proximal (duodenum or proximal jejunum) or distal (ileum or colon) obstruction, which will then guide further workup based on the differential diagnosis.

What Is the Next Step in Diagnosis?

If no free perforation is seen, an upper gastrointestinal (UGI) contrast series (■ Fig. 35.2) should be obtained to visualize the duodenum and proximal small intestine. If the patient is

acutely obstructed, this will be evident on the UGI. Sometimes, the volvulus spontaneously untwists. In this case the UGI will still demonstrate the malrotation, as the small bowel will all be to the right and fail to cross the midline.

Pathophysiology

What Defines the Midgut?

The midgut is the portion of the gut receiving blood supply from the superior mesenteric artery (SMA). In a fully developed fetus, it extends from the second part of the duodenum to two-thirds of the way across the transverse colon. The foregut structures are supplied by the celiac axis and the hindgut structures by the inferior mesenteric artery.

What Is the Normal Developmental Sequence of Events of the Human Midgut?

During the 6th week of gestation, the midgut elongates very rapidly and therefore must temporarily grow outside of the embryo. During this stage of umbilical herniation, the midgut rotates 90° counterclockwise around the axis of the SMA so that the proximal limb (small bowel) lies on the right side and the distal limb (colon) lies on the left side of the artery. Between the 10th and 12th week of gestation, the developing midgut returns into the abdominal cavity. The proximal limb passes behind the SMA and fixes to the left side of midline to form the duodenojejunal flexure or ligament of Treitz. The distal limb rotates counterclockwise a further 180° to place the cecum in its final position in the right lower quadrant and the transverse colon anterior to the SMA. The duodenum and ascending colon then become fixed in their final retroperitoneal positions. Proper midgut rotation allows the base of the small bowel mesentery to extend from the

ligament of Treitz diagonally down to the ileocecal junction, ensuring a broad base of attachment to the posterior abdominal wall.

What Is the Etiology of This Condition?

Malrotation results from failure of the midgut to rotate and fix properly, typically during its return into the abdominal cavity. Although there are various degrees of malrotation, classically the ligament of Treitz is situated to the right of midline, and the cecum fails to rotate the final 180° down to the right lower quadrant, placing it in the epigastrium.

Does Malrotation Always Result in Midgut Volvulus? Is It Always Acute?

No. The diagnosis of malrotation is not itself a surgical emergency. However, it predisposes the infant to midgut volvulus. It is also not always acute, and acute presentations vary from intermittent to complete obstruction. If the acute volvulus is incomplete or intermittent, the infant may appear well between episodes of vomiting. If the volvulus is chronic, the patient may present in childhood with chronic vomiting and recurrent abdominal pain or failure to thrive.

Workup

Are Plain Radiographs Always Necessary?

No. It is important to understand that if an infant has symptoms of acute gastrointestinal obstruction, has peritonitis, or is hemodynamically unstable, no additional evaluation is necessary. Rapid fluid resuscitation and immediate surgical intervention will provide the best chance at saving ischemic bowel.

Watch Out

In a patient with midgut volvulus, the most common bowel gas pattern seen on plain radiograph is normal. Suspicion should actually be heightened when a “normal” abdominal gas pattern is observed in an infant with bilious vomiting.

Management

What Is the Most Important Immediate Management Issue?

Acute midgut volvulus is a surgical emergency, and any delay in operating may result in gangrene of the entire midgut. The patient should be rapidly fluid resuscitated and taken to the operating room for urgent laparotomy. An orogastric or

nasogastric tube should be placed to decompress the stomach, and broad-spectrum antibiotics should be given while preparing for the operating room.

What Operation Is Required?

The Ladd's procedure. The goals of surgery are to relieve any intestinal obstruction and prevent recurrent volvulus. First, because volvulus typically occurs in a clockwise direction, the volvulus must be reduced by gently rotating the gut counterclockwise. Next, Ladd's bands, or the peritoneal attachments from the right upper quadrant to the ascending colon, must be divided. The duodenum is then straightened and examined for intrinsic obstruction. The base of the mesentery must be widened by dividing peritoneal adhesions. Finally, the small bowel is positioned on the right side of the abdomen and the large bowel on the left, in complete nonrotation. These positions ensure the maximum distance between the duodenum and the ileocecal junction. Because the cecum and appendix are now in the left upper quadrant, most surgeons perform an appendectomy to avoid future misdiagnosis in the event that the patient develops appendicitis.

Area Where You Can Get in Trouble

“Double-Bubble” Sign on Abdominal X-Ray in Neonate with Bilious Emesis

A relatively well-appearing baby with the classic “double-bubble” finding with absent distal gas on radiography is diagnostic of duodenal atresia. These patients develop epigastric distention because of a dilated stomach and proximal duodenum which resolves after nasogastric tube placement. Duodenal atresia results when there is a failure of the gut to recanalize and the lumen remains obliterated. This differs from the pathophysiology of jejunoileal atresia, which is thought to be a result of in utero vascular accidents leading to segmental intestinal ischemia and subsequent resorption. Since duodenal atresia is rarely a true surgical emergency, it is important that the child be adequately fluid resuscitated with correction of electrolyte imbalances preoperatively. If the patient is hypovolemic, induction of anesthesia or surgery itself may worsen existing hypotension or precipitate seizures due to electrolyte imbalances, end-organ damage from hypoperfusion, or cardiovascular collapse. Additionally, greater than 20% of infants with duodenal obstructions also have cardiac defects, and so this needs to be worked up with an echocardiogram.

Area of Controversy

Infants with Complete Midgut Infarction

Although the incidence of infants presenting with complete midgut infarction is low, the consequences are devastating.

Mortality rates are approximately 65% when more than 75% of the bowel is necrotic and much higher in the presence of other congenital anomalies. In the tragic case of complete midgut infarction, some advocate for closing the abdomen without resection and providing palliative care. If a massive small bowel resection is performed and the patient subsequently develops short gut syndrome (inadequate intestinal length to absorb sufficient nutrients), a future small bowel transplant may be necessary. Short bowel syndrome patients who are TPN dependent may develop TPN-associated liver failure and require a liver transplantation as well.

Summary of Essentials

History, Physical Examination, and Diagnosis

- Must determine bilious versus nonbilious emesis. Remember: green or yellow emesis = bilious emesis.
- Bilious vomiting during infancy (1–24 months) is a surgical problem until proven otherwise.
- Stable patient: plain abdominal radiographs first to exclude gross perforation
- If initial radiograph is negative: UGI contrast study to evaluate the duodenum and proximal small intestine.
- Always suspect malrotation with midgut volvulus in infants with bilious vomiting or children with bilious vomiting and abdominal pain.

Etiology/Pathophysiology

- Midgut is supplied by the superior mesenteric artery: second portion of duodenum → two-thirds of transverse colon.
- Malrotation due to developmental failure of normal 270° counterclockwise midgut rotation.
- Classic malrotation = narrow mesenteric base, ligament of Treitz located right of midline, cecum in the epigastrium, Ladd's bands from cecum to right upper quadrant, crossing duodenum.

- Volvulus = midgut rotates around superior mesenteric artery axis → duodenal obstruction, vascular compromise of bowel.
- Classic UGI radiograph: “corkscrew” appearance of contrast in bowel lumen.

Management

- Place nasogastric tube to decompress stomach; give antibiotics and IVF while preparing for laparotomy.
- Hemodynamically unstable infant with acute gastrointestinal obstruction → rapid fluid resuscitation, immediate surgical intervention without additional studies.
- Ladd's procedure: relieve obstruction by untwisting bowel; prevent future episodes by broadening mesenteric base.

Watch Out

- Malrotation with midgut volvulus may present with bilious or nonbilious vomiting depending on location of obstruction.
- Most common bowel gas pattern on plain radiograph is normal.
- During surgery, must exclude duodenal stenosis or atresia as cause of obstruction.
- Delay in diagnosis may result in complete midgut infarction.

Suggested Reading

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Infant with Nonbilious Emesis

Veronica F. Sullins, Rivfka Shenoy, and Steven L. Lee

Case Study

A 6-week-old full-term male is brought into the emergency room for nonbilious emesis. The mother reports that he began regurgitating breast milk 1 week ago. Although intermittent at first, nonbilious emesis now occurs after every feeding and has become progressively more forceful with increased volume. His appetite remains vigorous, even immediately after vomiting. He is the mother's first child and his delivery was uneventful. His blood pressure is normal and he is afebrile but tachycardic. On physical examination, he is irritable and has a sunken fontanelle. A small, firm mass is palpated in the right upper quadrant.

Diagnosis

What Is the Differential Diagnosis?

Table 36.1

Diseases managed medically	Diseases managed surgically
Acute gastroenteritis	Antral web
Gastroesophageal reflux disease	Enteric duplication cyst
Metabolic disorders (congenital adrenal hyperplasia, electrolyte imbalance, glycogen storage disease)	Gastroesophageal reflux disease
Pylorospasm	Pyloric atresia Pyloric stenosis

What Is the Most Likely Diagnosis?

Infantile hypertrophic pyloric stenosis (HPS). The incidence is approximately 1.5–4 in 1000 live births. HPS affects predominantly males over females, with reported ratios of 2:1 to 5:1 and is found more frequently in *firstborn males*. There is occasionally a positive family history.

History and Physical

Why Is It Important to Distinguish Between Bilious and Nonbilious Vomiting in an Infant?

The presence or absence of bile in the emesis is useful diagnostic information and is indicative of the anatomical location for the lesion. If the obstruction is proximal to the pylorus, the emesis will always be nonbilious. Bile-stained emesis implies that the obstruction is distal to the ampulla of

Vater. Children with *bilious emesis* are presumed to have a surgical problem (usually urgent/emergent) unless proven otherwise.

What Is the Classic History for HPS?

Projectile, nonbilious vomiting in an otherwise healthy infant is classic for HPS. The infant may have been vomiting for 1–2 weeks, but the emesis will become progressively more forceful and voluminous (consistent with progressively worsening pyloric stenosis). Infants will typically be brought to medical attention between 4 and 8 weeks, although the diagnosis can be made outside of this window.

What Are the Classic Physical Examination Findings?

A volume-depleted infant, as evidenced by a sunken fontanelle, with a palpable mass (described as an “olive”) in the right upper quadrant is classic for HPS. The “olive” represents a thickened and elongated pyloric muscle. However, if the infant is crying, the mass may not be palpable. Reverse peristaltic waves may also be seen in the upper abdomen. Physical examination of a crying infant can be quite challenging, so it is important to ensure that the child is warm and comfortable. Bending the legs and offering a pacifier (dipped in sugar water) are both helpful. With the classic history and palpable “olive,” there is no need for additional studies. However, if a mass still cannot be appreciated, further workup is warranted.

Pathophysiology

What Is the Pathophysiology of This Condition?

There is universal consensus that HPS is characterized by hypertrophy and hyperplasia of the circular muscle layer of the pylorus. Muscle thickening causes the pyloric channel to become increasingly narrowed and elongated, eventually leading to gastric outlet obstruction. The smooth muscle of the stomach hypertrophies and dilates in response to vigorous peristalsis against an obstructed pylorus. As the stomach dilates and peristaltic contractions become stronger, the classic projectile vomiting of a large volume of gastric content occurs.

Watch Out

There is a reported association with use of oral erythromycin and HPS in infants.

Workup

What Is the First Imaging Study to Obtain?

If there is no palpable “olive,” the gold-standard imaging modality is ultrasonography. Ultrasound measurements of pyloric channel length, muscle thickness, and diameter will diagnose HPS with a sensitivity and specificity close to 100%. Most consider pyloric thickness greater than 3–4 mm and length greater than 15–16 mm diagnostic of HPS (■ Fig. 36.1). However, exact measurements vary based on the patient's age and weight, so findings should be interpreted within the clinical context. Hyperactive peristalsis and lack of content traversing the pylorus will often be seen on US and help confirm the diagnosis.

What if the Diagnosis Is Still Uncertain?

If ultrasound is equivocal, the diagnosis may be made with an upper gastrointestinal (UGI) contrast study. Typical findings include delayed gastric emptying, retrograde peristalsis in the stomach, and a *string sign* at the level of the pylorus. UGI studies may also be helpful in the setting of a negative ultrasound in order to assess for other pathology, particularly malrotation and gastroesophageal reflux.

Watch Out

Contrast UGI studies have a risk of causing aspiration in infants, especially those with HPS (since they have gastric outlet obstruction), and should therefore be reserved for cases where the diagnosis is uncertain or malrotation with midgut volvulus cannot be ruled out.

Watch Out

In premature or small infants or in patients who present early in the disease process, ultrasound measurements may not meet criteria for HPS, as the thickness of the pylorus increases over time. This may lead to a false-negative study.

What Electrolyte Abnormalities Would You Expect?

Protracted, nonbilious vomiting results in a *hypochloremic, hypokalemic metabolic alkalosis*. Chloride ions are lost in gastric secretions, and alkalosis is initially caused by loss of gastric HCl. Hypokalemia is a result of the combination of potassium ions being lost with vomiting and kidney excretion of K^+ . Volume depletion and subsequent hypovolemia increase aldosterone secretion, which in turn leads to activation of the Na^+/K^+ pump in the renal tubules. In an attempt to increase water reabsorption, Na^+ is conserved at the expense of K^+ excretion (this is the main driver of K^+ loss). As K^+ levels in the blood decrease, the kidney preferentially uses Na^+/H^+ pump to maintain Na^+ and water reabsorption and prevent profound hypokalemia. This change leads to H^+ secretion and worsens the metabolic alkalosis. Accordingly, urinalysis often reveals paradoxical aciduria.

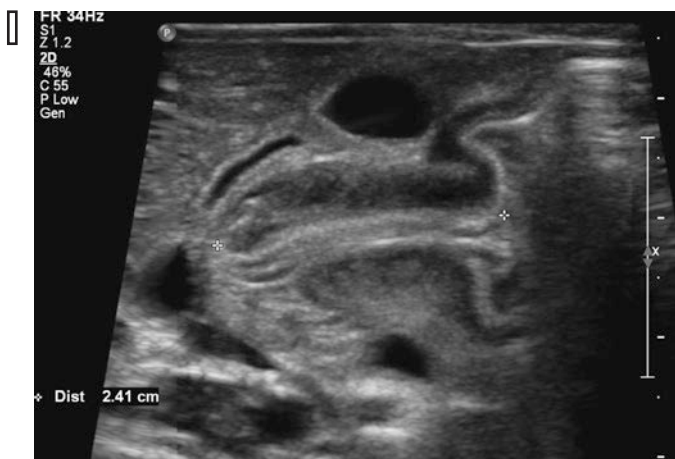
Management

What Is the Most Important Immediate Management Issue?

The first step in management is to secure intravenous access and begin fluid resuscitation. Volume depletion in patients with HPS is common due to prolonged, high-volume emesis. An initial isotonic fluid (normal saline) bolus of 20 ml/kg should be given to children with severe volume deficits. A nasogastric tube is not routinely necessary. Any electrolyte abnormalities should be corrected prior to taking the patient to the operating room.

Watch Out

Children have a higher body surface area-to-volume ratio than adults and are therefore more sensitive to volume loss. Any child with physical exam findings (decreased skin turgor, sunken fontanelle) or vital sign derangements should be considered to have moderate to severe hypovolemia.



■ Fig. 36.1 Ultrasound image of pyloric stenosis (pyloric length is 24 mm)

What Is the Treatment?

Surgery provides definitive treatment for pyloric stenosis. The procedure of choice is a pyloromyotomy. The abdomen is entered either laparoscopically or through a small transverse right upper quadrant incision. The pylorus is identified, and an incision is made through the overlying serosa and the thickened pyloric muscularis. The pylorus muscle is then spread apart until the intact submucosa and mucosa are seen. Air or methylene blue is instilled through a nasogastric tube into the stomach to confirm there is no leak.

Watch Out

Remember that HPS is a medical emergency, not a surgical one. Restoration of fluids and electrolytes is paramount.

What Is the Timing of Surgery?

Surgery is delayed until effective fluid resuscitation and electrolyte replacement have been performed. While not an emergency, surgery should be performed during the same admission. Most patients require 24 hours for adequate resuscitation. Patients with severe volume depletion may require a longer period of repletion prior to surgery. In general, patients are optimized for surgery when there is adequate urine output, the serum bicarbonate is less than 30 mmol/L, and the serum potassium is normal.

When Can the Patient Resume Eating?

Following surgery, many children may begin oral feeding within a few hours. There continues to be wide variation in structured feeding regimens. It is very common, however, for patients to vomit after surgery. This is most often due to either postoperative edema around the pylorus or, less commonly, an incomplete pyloromyotomy. Edema will resolve over a few days and the vomiting will subside. An incomplete pyloromyotomy will not likely resolve, and the patient may require a repeat operation. Persistent vomiting beyond 3–4 days postoperatively is often indicative of this complication. Patients are typically discharged home 1 day after surgery.

Areas Where You Can Get in Trouble

Inadequate Resuscitation Prior to Surgery

Operating prior to adequate resuscitation is perilous for children with HPS. Anesthesia induction in hypovolemic children with electrolyte disturbances may precipitate catastrophic outcomes, including cardiovascular collapse and

death. Children with severe electrolyte derangements or kidney disease may experience rapid fluid and electrolyte shifts, and potassium repletion in the setting of hypovolemia could lead to iatrogenic hyperkalemia or seizures.

Postoperative Complications

In performing a pyloromyotomy, the surgeon must strike a balance between the risk of perforation and the risk of inadequate pyloromyotomy. Myotomies that are too superficial or too short do not adequately treat the primary disease process. Emesis beyond 3–4 days postoperatively should prompt an UGI evaluation to assess for incomplete pyloromyotomy. If there is persistent stenosis, reoperation may be required. Alternately, if the incision is made too deep (through the submucosa and mucosa), the myotomy becomes a full-thickness pyloric injury. This may result in leakage of gastric secretions and/or enteric contents. If the injury is recognized during surgery, it may be repaired immediately. Postoperatively, a leak may first present with fever or tachycardia, followed by feeding intolerance and leukocytosis. If not recognized early, the patient may subsequently develop peritonitis and sepsis. If a perforation is diagnosed postoperatively, the patient must be emergently taken back to the operating room for exploration. Surgical management depends on the stability of the patient and the degree of contamination (contained versus uncontained leak).

Area of Controversy

Nonsurgical Management

In North America, surgical management remains the standard of care; pyloromyotomy is regarded as the definitive treatment. Some European centers attempt diet modification and/or prolonged inpatient supportive care while awaiting resolution of the muscular hypertrophy. In some Asian countries, atropine has been used to medically manage HPS with variable success.

Summary of Essentials

History, Physical Examination, and Diagnosis

- Always determine if vomiting is bilious (green or yellow) or nonbilious.
- Most common surgical cause of nonbilious vomiting in an infant: HPS.
- Classic history: projectile, nonbilious vomiting in healthy 4–8-week-old male.
- Classic physical examination: palpable right upper quadrant “olive” mass, visible peristalsis over the epigastrium (ensure patient is calm during exam).

- Ultrasound if diagnosis is unclear.
- Diagnostic criteria.
- Pyloric length >15 mm.
- Thickness >3 mm.
- Common electrolyte abnormalities common: hypochloremic, hypokalemic metabolic alkalosis and paradoxical aciduria.

Pathophysiology

- Etiology not known
- Hyperplasia and hypertrophy of pylorus → gastric outlet obstruction

Management

- Medical management first: fluid resuscitation, correct electrolyte imbalances.

- Pyloromyotomy is the gold standard: incise and split the muscular layers, leaving the mucosa and submucosa intact.
- Delay surgery until infant is resuscitated and electrolyte levels are normal (may take 24–48 hours).
- Feeding starts hours after surgery; vomiting is common but should resolve.

Suggested Reading

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Infant Born with Abdominal Wall Defect

Justin P. Wagner, Rivfka Shenoy, and Steven L. Lee

Case Study

An infant at 39-week gestation is born to a thin 19-year-old Caucasian grava-1, para-0 woman with no prior medical history. Her body mass index (BMI) is 20. She quit smoking when she discovered she was pregnant. The pregnancy was uncomplicated. Prenatal maternal laboratory studies were significant for an elevated serum alpha-fetoprotein (AFP) level. Prenatal ultrasound examinations showed a fetus with free loops of intestine present in the amniotic cavity extruding through a small abdominal defect lateral to the base of the umbilical cord. The infant's APGAR scores are 8 and 9 at birth and 5 min later, respectively. Vital signs are within normal limits. The abdomen is scaphoid with loops of matted and inflamed small bowel protruding from a defect to the right of the umbilicus.

Diagnosis

What Is the Differential Diagnosis for a Newborn with Abdominal Wall Defect and What Are the Common and Distinguishing Features?

Table 37.1

Diagnosis	Common features	Distinguishing features
<i>Gastroschisis</i>	Medial abdominal wall defect with evisceration of abdominal contents	No membrane over abdominal contents
		Evisceration usually to the <i>right</i> of umbilical stalk
		Higher risk to intestinal viability
		Diagnosis impossible before 12 weeks
<i>Omphalocele</i>	Midline abdominal wall defect with herniation of abdominal contents	Amnioperitoneal membrane covers abdominal contents
		Umbilical cord inserts into membrane
		Associated with other birth defects
		Diagnosis possible before 12 weeks only if liver herniation present

Table 37.1 (Continued)

Diagnosis	Common features	Distinguishing features
<i>Bladder or cloacal exstrophy</i>	Extra-abdominal/pelvic sac containing herniated hemibladders, urethra, and possibly kidney and intestine	Defect usually inferior to umbilical stalk
		Two hemibladders separated by intestine
		Extensive defects associated with omphalocele and epispadias
		Sacral and pelvic bone defects including pubic diastasis
<i>Prune belly syndrome</i>	Partial or complete absence of abdominal wall muscles	Thin, wrinkled and loose abdominal skin, with viscera visible underneath
		95% are in males
		Associated with hypoplastic prostate, bilateral undescended testes, infertility, and bladder outlet obstruction
<i>Urachal abnormality</i>	Communication of bladder and anterior abdominal wall; may be associated with cyst or sinus	Communication between bladder and a cystic mass pathognomonic for patent urachus
		Often associated with omphalocele and neural tube defects

What Is the Most Likely Diagnosis in This Case?

Gastroschisis is the most likely diagnosis. The infant's mother has several risk factors associated with gastroschisis, including young age, Caucasian race, low BMI, singleton pregnancy, and recent tobacco use. Prenatal ultrasound detects gastroschisis in about 70% of cases. It is effective in distinguishing gastroschisis from omphalocele, and it is useful to evaluate visceral blood flow. In this case, the patient is born with eviscerated bowel and no sac, strongly suggesting a diagnosis of gastroschisis (Fig. 37.1a).



Fig. 37.1 Gastroschisis a and omphalocele b

History and Physical Examination

Which of the Above Diagnoses Are the Most Common?

Gastroschisis occurs in 2–4 in 10,000 live births, while omphalocele occurs in 1 in 4000–5000 live births. The rest of the conditions are rare, occurring in fewer than 1 in 40,000 live births.

What Are the Specific Differences Between Gastroschisis and Omphalocele?

Table 37.2

Factor	Gastroschisis (Fig. 37.1a)	Omphalocele (Fig. 37.1b)
Location	Paraumbilical (usually right side)	Umbilical
Defect size	Often small (<5 cm)	Variable, often large
Cord insertion	Normal in umbilicus	Inserts in membrane
Membrane	Absent	Present (10–20% rupture)
Contents	Bowel (gonads, liver, stomach)	Bowel, liver

Table 37.2 (Continued)

Factor	Gastroschisis (Fig. 37.1a)	Omphalocele (Fig. 37.1b)
Bowel	Matted, dilated, or thickened	Normal
Malrotation	Often present	Present
Abdominal cavity	Small	Small
Maternal AFP level	Elevated (greater than omphalocele)	Elevated
Intrauterine growth restriction (IUGR)	Present	Absent
GI function	Ileus	Normal
Associated GI anomalies	Intestinal atresia (10–25%)	Nonspecific, but higher overall risk
Other associated anomalies	Rare	Common (30–70%) Beckwith-Wiedemann, trisomies 13 and 18, Pentalogy of Cantrell Chromosomal in 50–70% without liver herniation

AFP alpha-fetoprotein

What Are the Risk Factors for Gastroschisis and for Omphalocele?

Table 37.3

Maternal risk factor	Gastroschisis	Omphalocele
Age	<20 years	<20 or >40 years
Race	Caucasian	–
Pregnancy	Singleton	–
BMI	Low	High
Medical history	Frequent UTIs	SSRI use may be associated
	Aspirin use	Heredity/associated heritable conditions in family history
	Gestational diabetes	
Social	Cigarette smoking	–
	Recreational drug use	
	Alcohol consumption	
	Unmarried	

UTI urinary tract infection, SSRI selective serotonin reuptake inhibitor

the base of the umbilical cord and undergoes proliferation and rotation. The viscera return to the peritoneal cavity at fetal week 11 of gestation. Omphalocele is a result of persistent herniation of viscera contained within a sac that never returned to the abdomen during development. The failure of cell migration may be a manifestation of an underlying disease process that affects several other migrating cell types during development. Frequently, omphalocele is part of an association of birth defects with a common congenital cause. When the liver is extracorporeal (i.e., when a large defect is present), a chromosomal abnormality is unlikely.

Which Condition Is More Urgent? Why?

Gastroschisis generally creates more urgent problems at delivery that require immediate pediatric surgical intervention. This derives from two problems: the fact that the bowel is not covered by a protective membrane and the associated intestinal abnormalities. The longstanding exposure of the bowel in utero to amniotic fluid often leads to markedly inflamed bowel. Soon after delivery, the exposed viscera should be protected and the patient evaluated to determine the extent of intestinal anomalies. Concurrent malrotation with volvulus or intrauterine vascular compromise may result in intestinal atresia, obstruction, stenosis, necrosis, or perforation. Furthermore, the exposed bowel creates significant risk of insensible fluid and heat losses that can be substantial if the bowel remains unprotected. With omphalocele, the membrane covering the bowel protects against these urgent problems. Of greater long-term concern for patients with omphalocele however, are the associated conditions such as Pentalogy of Cantrell, trisomy 13, and trisomy 18, all of which carry poor prognoses.

Pathophysiology

What Is the Etiology of Gastroschisis?

While the etiology of gastroschisis is relatively unclear, it is thought to result from a *vascular accident* within the umbilical ring, leading to a local defect in the developing body wall and evisceration. Experts hypothesize the involution of the right umbilical vein leads to a defect that is most often to the right of the umbilicus. The disease process is commonly limited to the local body wall defect and the herniated viscera.

What Is the Etiology of Omphalocele?

Omphalocele is thought to develop from an arrest of lateral-body fold migration and body wall closure. This process takes place during the organogenesis phase. At embryonic week 5 of normal development, the midgut extrudes through

Workup

What Is the Next Step in the Workup?

Postpartum stabilization is the top priority for infants born with gastroschisis and omphalocele, and diagnostic testing is reserved for the most critical issues. The airway, breathing, and circulation are evaluated and stabilized. Metabolic disturbances are evaluated with blood laboratory testing. Intravenous fluid intake and urine output are closely monitored, and x-rays are performed to evaluate general anatomy and the positions of implanted devices (i.e., endotracheal tubes, central venous catheters, and orogastric tubes). Stabilized infants with omphalocele undergo *echocardiography* to evaluate for associated congenital cardiac defects.

Management

What Is the Neonatal Management of Gastroschisis and Omphalocele?

At the time of delivery, the top priorities in the management of an infant with either gastroschisis or omphalocele include airway protection, thermal support, protection of herniated viscera, establishment of intravenous access, and fluid resuscitation. Importantly with gastroschisis expeditious placement of a sterile plastic bag or wrap protects exposed viscera from rapid heat and fluid loss. Small defects in either case may be repaired surgically. Larger defects with more protruding viscera require placement of herniated contents in a Dacron-coated silastic silo. This maneuver permits gradual resolution of visceral inflammation and reduction into the peritoneal cavity. Infants with gastroschisis often develop prolonged ileus from intestinal inflammation, and so they require parenteral nutritional support during this phase. Omphaloceles rupture in up to 20% of cases, either in utero or at the time of delivery. In the case of rupture, management is identical to that of gastroschisis. For giant omphaloceles, a caesarean section may minimize the risk of traumatic rupture during delivery, though there is no evidence that caesarean delivery improves omphalocele outcomes.

What Is the Timing of the Closure of the Abdominal Wall Defect?

The defect is surgically repaired when the herniated contents have reduced significantly and there is sufficient abdominal

wall laxity to accommodate a low-tension repair. Small gastroschisis and omphalocele defects may undergo primary operative repair if the contents reduce easily. For large defects that have been temporized with a silo, contents are gradually reduced each day into the abdominal cavity, and once there is no tension, the defect can be closed (■ Fig. 37.2).

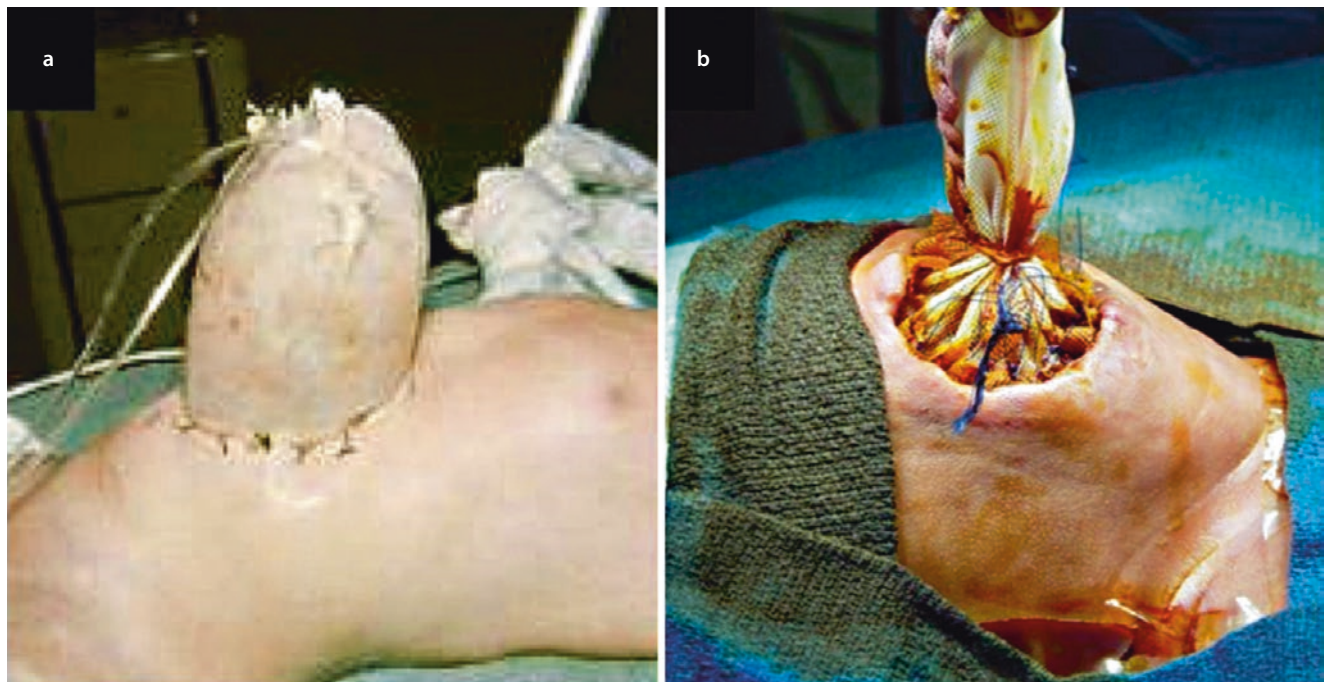
Areas Where You Can Get in Trouble

Not Properly Protecting the Bowel

Upon securing the airway, thermal support is usually provided by a heating lamp. The viscera are wrapped with a sterile plastic covering. Saran Wrap is a reasonable temporizing option if there is a delay in acquiring a silo. Moist gauze dressings alone should be avoided because the infant can lose significant fluid and heat without a watertight plastic dressing.

Not Addressing Nutritional Needs

The appearance of the bowel will dictate the nutritional support the child receives. Matted, inflamed intestines will likely be slow to function and ileus is likely. In cases where gastrointestinal dysmotility is suspected, the infant should be supported with total parenteral nutrition (TPN) until the bowel is functional.



■ Fig. 37.2 Initial silo placement for gastroschisis a and complete reduction b

Not Recognizing Abdominal Compartment Syndrome After Repair

After the defect is surgically repaired, the infant must be monitored closely for signs of increased intra-abdominal pressure. Low urine output, insufficient ventilation, tense abdominal distension, and positive fluid balance signify development of abdominal compartment syndrome. Prolonged mechanical ventilation may be necessary after reduction and abdominal closure.

Area of Controversy

Method of Repair of Large Abdominal Wall Defect

When defects are large and reduction into the peritoneal cavity is limited, definitive surgical repair is more complex. For giant omphaloceles, a topical sclerosing agent may be applied to the sac and the defect edges to promote reduction. The defect can be covered with an inert sheet, leaving a large ventral hernia that can be sequentially folded inward, and ultimately covered with skin grafts. Additionally, tissue expanders may be implanted to generate enough abdominal domain to cover the volume of displaced viscera.

Summary of Essentials

Diagnosis

- Prenatal ultrasound is diagnostic in most cases.
- Gastroschisis is paraumbilical (typically to the right of the umbilicus) and has exposed bowel.
- Omphalocele has a sac (the umbilicus inserts into the sac) and is associated with more congenital defects.

Omphalocele-Associated Conditions

- Beckwith-Wiedemann Syndrome
- Trisomy 13

- Trisomy 18
- Pentalogy of Cantrell

Etiology

- Gastroschisis: in utero vascular insult, abdominal wall defect
- Omphalocele: arrest of cell migration, incomplete return of midgut to the peritoneal cavity

Neonatal Management

- Ventilation
- Normothermia and fluid management:
 - Radiant heater
 - Orogastric suction
 - Protect exposed viscera with plastic wrap
 - IV fluids and broad-spectrum antibiotics
 - Gastroschisis: surgical evaluation for atresia, ischemia, or volvulus; low threshold to start TPN
 - Primary surgical repair versus protective silo and serial reduction
 - Surgical repair

Postoperative Care

- Ventilator requirement after reduction may persist.
- Administer TPN if necessary.
- Monitor for abdominal compartment syndrome.

Suggested Reading

- Henrich K, Huemmer HP, Reingruber B, Weber PG. Gastroschisis and omphalocele: treatments and long-term outcomes. *Pediatr Surg Int.* 2008;24(2):167–73.
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Excessive Drooling in a Newborn

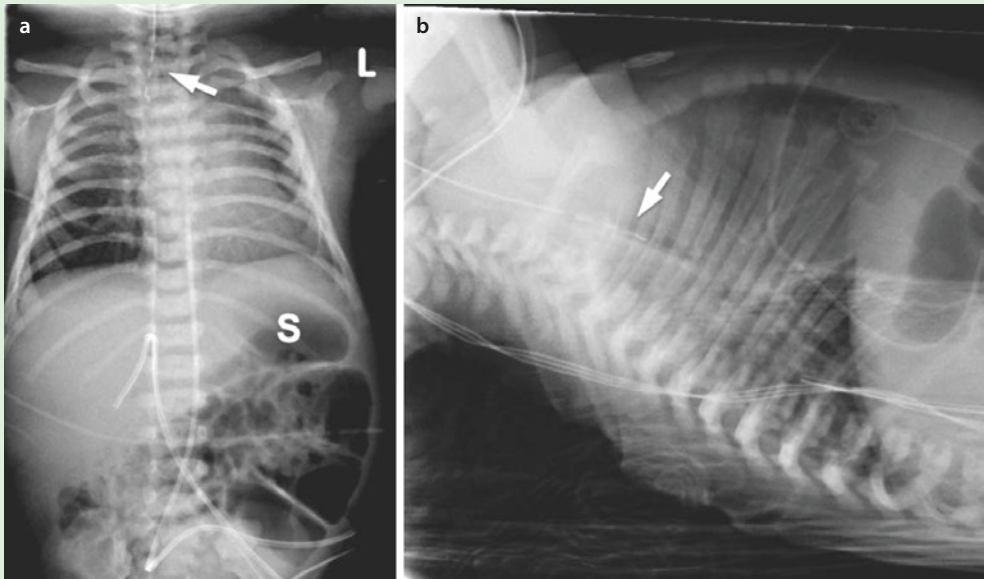
Veronica F. Sullins, Rivfka Shenoy, and Steven L. Lee

Case Study

A full-term female newborn presents with excessive drooling. She is noted to have white frothy mucus building up in her mouth and nose, which recurs despite suctioning. She is also unable to tolerate any feedings. During her first

feeding, she gagged and immediately spit up. There were no complications during birth. On examination, the newborn is normotensive and has a normal heart rate. Her oxygen saturation is 98% but decreases to 80% during

feeding. She has bilateral rales and ronchi on lung auscultation. Her abdomen is distended and nontender. The patient receives anteroposterior and lateral chest radiographs after orogastric tube placement (■ Fig. 38.1).



■ Fig. 38.1 a, b Anteroposterior and lateral chest radiographs after orogastric tube placement (arrows). The stomach (S) is shown in the anteroposterior radiograph

Diagnosis

What Is the Differential Diagnosis of Excessive Drooling/Feeding Intolerance in a Newborn?

■ Table 38.1

Diagnosis	Distinguishing features
Choanal atresia	Neonates obligate nasal breathers (inability to pass NG tube)
Cleft palate	Defect seen on physical examination of the oral cavity
Esophageal atresia with or without tracheo-esophageal fistula	OG/NG tube seen curled in upper esophageal pouch on AP and lateral radiographs
Esophageal web or ring	Usually asymptomatic until later in life, vomiting if symptomatic, circumferential partial obstruction on contrast esophagram
Food sensitivity	Normal anatomy, accompanying rash or diarrhea, specific food intolerance
Gastroesophageal reflux	Normal anatomy, frequent regurgitation or vomiting
Laryngotracheoesophageal cleft	Midline defect between posterior wall of larynx/trachea and anterior esophagus
Mediastinal or tracheal compression	Extrinsic compression of esophagus, lesion (tumor, vascular ring, foregut duplication, etc.) on chest XR, ultrasound, or CT scan
Neurologic disorder	Patent esophagus on contrast esophagram, uncoordinated peristalsis on swallow study

NG nasogastric, OG orogastric, AP anteroposterior, XR radiograph, CT computed tomography

What Is the Most Likely Diagnosis?

Esophageal atresia (EA) with distal tracheoesophageal fistula (TEF) is the most likely diagnosis. Chest radiographs show the orogastric tube curled in the upper esophageal pouch confirming the diagnosis of EA. The presence of air in the gastrointestinal tract suggests a connection from the trachea to the distal esophagus or a distal TEF. Absence of a gastric bubble is diagnostic of either EA without a TEF or EA with a proximal TEF. Focal infiltrates may indicate pneumonia secondary to aspiration of gastric contents or feedings.

History and Physical

What Are Other Possible Presentations of TEF?

In addition to excessive drooling or choking with feeds, newborns may also present with respiratory distress or pneumonia. The presentation of TEF is determined by the presence or absence of EA as well as the presence and severity of associated anomalies. Patients with small fistulas with a normal esophagus (H-type) may be asymptomatic and will not present until later in life with recurrent pneumonia or respiratory distress with feeding.

Pathophysiology

What Is the Significance of Oxygen Desaturation that Only Occurs While Feeding?

Normal oxygen saturation at rest implies intact tracheobronchial anatomy. When a newborn has desaturations while feeding, it implies that there is a significant anatomic or functional problem with the proximal alimentary tract (nasopharynx, oropharynx, esophagus, or stomach).

What Is Thought to Be the Etiology of EA?

Although the pathogenesis remains unknown, EA with or without TEF is thought to be caused by a defect in the development of the longitudinal tracheoesophageal fold that separates the most caudal part of the primitive foregut into the trachea and esophagus. It is believed that the fistula tract is derived from defective epithelial-mesenchymal interactions in a branch of the embryonic lung bud that fails to develop. An alternate theory is that the primitive foregut occludes, and then there is a failure of recanalization.

How Are the Different Types Classified?

EA and TEF are classified by their anatomic configuration, specifically the location of the TEF (■ Fig. 38.2). The *most common is type C*, a proximal esophageal pouch with a distal TEF, accounting for approximately 85% of cases. The next most common is pure EA without TEF, also known as type A (8%).

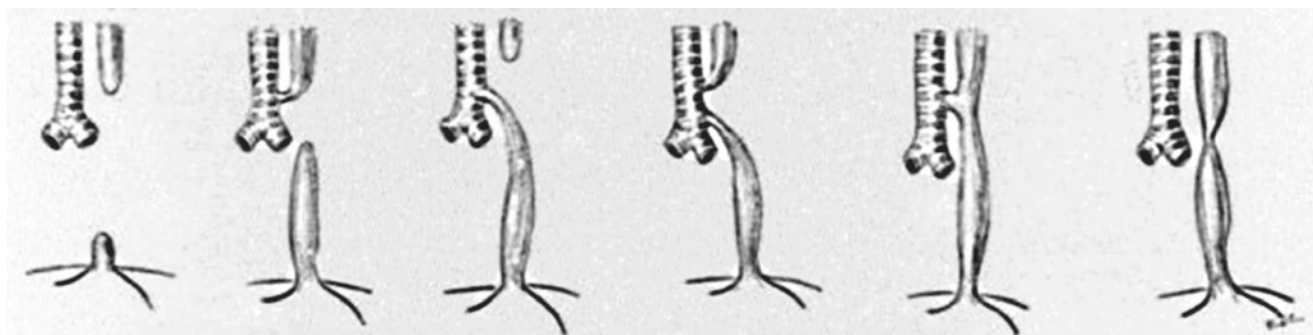
What Are the Associated Anomalies?

Approximately 50% of children with TEFs have associated anomalies including cardiac, urogenital, skeletal, vertebral, anorectal, gastrointestinal, and palatal or laryngeal anomalies. Associations and syndromes known as VACTERL (■ Table 38.2) are frequently diagnosed. In addition, there are reports of associations with trisomies 18, 21, and 13 as well as single-gene deletions. The most common associated anomalies are cardiovascular.

Work-up

What Is the Best Initial Diagnostic Test?

If the newborn is stable, the best initial study is a chest radiograph (anteroposterior *and* lateral) after placement of a



■ Fig. 38.2 a–f Gross classification of esophageal atresia and tracheoesophageal fistula. (From Coran AG, et al. *Pediatric Surgery*, 7th edition. Copyright Elsevier (2012). Reprinted with permission)

Table 38.2 Anomalies found in VACTERL

Category of anomaly	Specific anomalies
Vertebral	Hypoplastic or hemivertebrae
Anorectal	Anal atresia or imperforate anus
Cardiovascular	ASD, VSD, tetralogy of Fallot, truncus arteriosus, transposition of the great arteries
Tracheoesophageal	Tracheoesophageal fistula
Esophageal	Esophageal atresia
Renal	Renal agenesis, hypoplastic or dysplastic kidney, horseshoe kidney, renal ectopia, ureteral obstruction, vesicoureteral reflux
Limb	Displaced or hypoplastic thumb, polydactyly, syndactyly, radial aplasia

ASD atrial septal defect, VSD ventricular septal defect

nasogastric or orogastric tube. Abnormal lung fields may demonstrate a pneumonia, primary lung lesion, or congenital diaphragmatic hernia. EA is diagnosed by visualization of the nasogastric or orogastric tube coiled in the upper mediastinum, posterior to the larynx or trachea. A diagnostic algorithm for surgical causes of neonatal feeding intolerance is shown in [Fig. 38.3](#).

Watch Out

An anteroposterior chest radiograph alone may incorrectly diagnose EA if the naso- or orogastric tube is misplaced. A lateral chest radiograph is necessary to confirm that the tube is curled in the upper esophageal pouch and not the trachea or larynx.

Watch Out

Contrast esophagrams have a risk of causing aspiration pneumonia and should therefore be reserved for cases where the location of the fistula cannot be ascertained or the diagnosis is uncertain.

Can the Diagnosis of TEF Be Made Prenatally?

It is difficult to determine prenatally if a newborn has a TEF as air will not have entered into the alimentary tract through the fistula until after birth. However, EA may be manifested by polyhydramnios on prenatal ultrasound.

Management

What Is the First Step in Clinical Management?

If the patient is exhibiting signs of respiratory compromise, endotracheal intubation and mechanical ventilation are required. Preoperative management is aimed at minimizing the risk of aspiration. This may be achieved by continuous suction of the blind upper esophageal pouch and elevation of the infant's head. For patients who have developed pneumonia, broad-spectrum antibiotics should be given, and a gastrostomy tube may be placed to prevent further reflux into the trachea. Patients without a pulmonary infection should be started on prophylactic antibiotics.

Watch Out

Every effort should be made to avoid distending the gastrointestinal tract to avoid further aspiration and lung injury. This is especially important for patients who are receiving ventilator support. Avoid the use of bag valve masks.

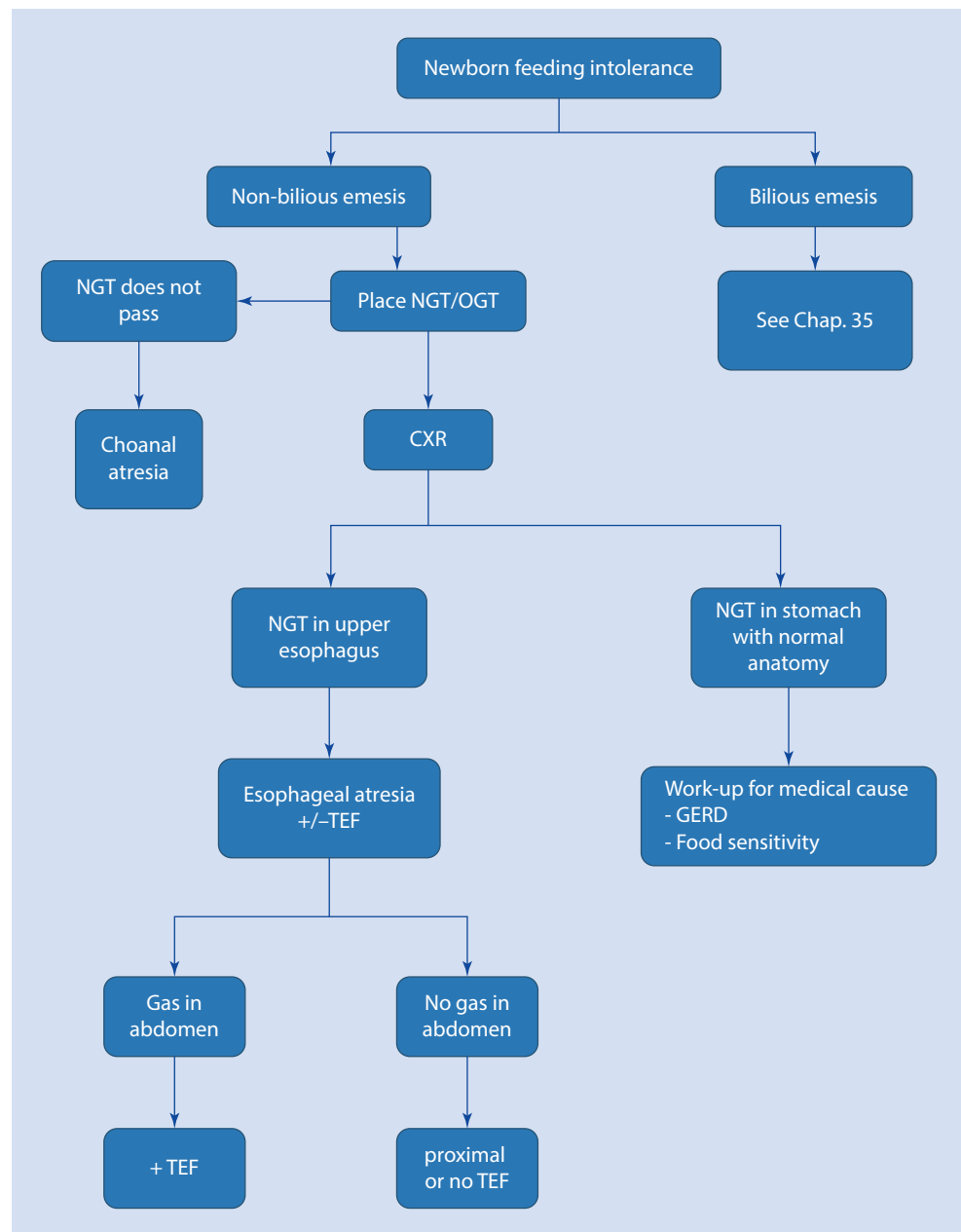
Are Other Studies Necessary for Diagnosis?

No. A history of newborn feeding intolerance and excessive drooling combined with the above chest radiographs are diagnostic. If the history is unclear or the radiographic findings are equivocal, a contrast esophagram may be performed by instilling barium through a catheter inserted into the esophagus and taking both lateral and anteroposterior radiographs. The improved quality of CT scans has made three-dimensional imaging popular; however, it exposes the newborn to a much larger radiation dose and is not usually necessary to make the diagnosis.

What Is the Timing of Surgical Repair?

The timing of surgery is based on the size and condition of the infant. Healthy infants with proximal EA and distal TEF (Type C) may undergo surgical repair within the first few days of life. Patients with severe anomalies or respiratory failure secondary to pneumonia should have ligation of the TEF and placement of a gastrostomy tube for feeding, and definitive repair should be delayed until their clinical status improves. Surgery may be delayed several weeks especially in cases of severe respiratory distress syndrome or prematurity. Definitive treatment consists of surgical division of the fistula tract with repair of the trachea and primary anastomosis of the esophagus.

Fig. 38.3 Diagnostic algorithm for neonatal feeding intolerance



Are Any Other Studies Needed Prior to Surgery?

Even stable infants who are fit for early repair must have a complete work-up including thorough physical exam, cardiac and renal ultrasounds, and plain radiographs to evaluate for associated anomalies (Table 38.2) prior to operation. In addition, *echocardiography* provides essential anatomic information required for surgical repair.

What Are the Complications After Surgical Repair?

Approximately 15% of patients have a leak at the esophageal anastomosis. Typically, leaks heal spontaneously, resulting in

a stricture. If a leak occurs within the first few days postoperatively, surgical revision is usually required. Anastomotic strictures are very common and may be as high as 80%. Typical management includes esophagoscopy and balloon dilation of the stricture. Gastroesophageal reflux disease is very common after TEF repair, and such reflux is associated with an increased risk of Barrett's esophagus and esophageal cancer. Long-term, approximately 30% will need a surgical anti-reflux procedure. Recurrence of the TEF has also been described and requires surgical repair.

What Is the Prognosis?

In infants without severe associated anomalies, survival rates are near 100%. However, patients may have significant

morbidity including anastomotic leak, tracheomalacia, gastroesophageal reflux disease, dysphagia, esophageal dysmotility, and pulmonary problems due to recurrent aspiration. In infants with significant comorbid conditions or who are not candidates for early repair, the survival rate is 80–95%. Those with low birth weight and major cardiac anomalies have the lowest survival rates.

Area Where You Can Get in Trouble

Intubation and TEF

In the presence of a TEF, intubation and mechanical ventilation should be avoided if possible. Positive pressure ventilation may result in significant gastric and abdominal distension due to air moving through the TEF and into the alimentary tract instead of into the lungs. Increasing abdominal distention and pressure decreases lung expansion and further compromises respiratory status. In addition to making single-lung ventilation during surgical repair more tenuous, excessive amounts of air in the digestive tract may cause perforation and emergency operation.

Summary of Essentials

Diagnosis

- Differential diagnosis of feeding intolerance is broad: includes anatomic malformations of naso- and oropharynx, tracheobronchial tree, and esophagus, GERD, extrinsic esophageal compression, food sensitivity, and neurologic disorders.

History and Physical Examination

- Desaturations only while feeding imply anatomic or functional problem within proximal aerodigestive tract

- Best initial diagnostic test: anteroposterior and lateral chest radiography after nasogastric or orogastric tube placement

Pathophysiology

- EA ± TEF caused by defect in the development of longitudinal tracheoesophageal fold separating foregut into trachea and esophagus.
- EA and TEF classified according to the location of the TEF: EA with a distal TEF (Type C) most common.
- >50% have associated anomalies: cardiovascular most common, frequent VACTERL association.
- Excellent prognosis in absence of significant anomalies, but patients may have significant clinical sequelae resulting from surgical repair.

Management

- Patients with respiratory compromise → Intubation and mechanical ventilation.
- Preoperative management goal: minimize risk of aspiration (naso- or orogastric suction of upper esophageal pouch, head elevation, antibiotics).
- All need evaluation for associated anomalies: echocardiogram, renal ultrasound, radiographs.
- Timing of surgery depends on patient's clinical condition, size, and presence of associated anomalies.

Suggested Reading

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- Kunisaki SM, Foker JE. Surgical advances in the fetus and neonate: esophageal atresia. *Clin Perinatol.* 2012;39(2):349–61.
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Question Set:

Pediatric Surgery

Questions

1. A 6-week-old boy presents with a 6-day history of non-bilious, forceful vomiting. Between episodes of vomiting, the baby feeds vigorously. On physical exam, the baby has dry mucous membranes with a sunken anterior fontanelle. Capillary refill is 2 s. He is otherwise asymptomatic without findings on physical exam. Ultrasound is obtained and demonstrates a thickened pyloric channel. What electrolyte abnormality would you expect?
- (A) Hypochloric metabolic alkalosis
 - (B) Hyperkalemic metabolic acidosis
 - (C) Hyponatremic metabolism acidosis
 - (D) Hyperkalemic metabolic alkalosis
 - (E) Hyponatremic metabolic alkalosis
2. A 2-h-old male born at 39-weeks' gestation is noted to have difficulty breathing. Which of the following would most strongly suggest a diagnosis of esophageal atresia with a tracheoesophageal fistula?
- (A) Worsening respiratory status with feeding
 - (B) Olive-shaped mass palpable in the epigastric region
 - (C) Improvement of respiratory status over 24-h after birth
 - (D) Chest x-ray showing dilated loops of small bowel in the left hemithorax
 - (E) Scaphoid abdomen
3. A 2-h-old male born at 39-weeks' gestation with difficulty breathing is diagnosed with esophageal atresia with a tracheoesophageal fistula and undergoes surgical repair, which was uncomplicated. Ten years later, the patient develops difficulty swallowing and often vomits undigested food shortly after eating. Which of the following is the most likely explanation for this?
- (A) Scleroderma
 - (B) Gastroesophageal reflux
 - (C) Esophageal cancer
 - (D) Esophageal leak
 - (E) Esophageal stricture
4. A 2-week-old male infant born at 26-weeks' gestation is in the neonatal ICU when he becomes hypotensive and begins passing bloody stools. Which of the following is the most likely finding?
- (A) Palpable olive-shaped mass in the epigastric region
 - (B) Double-bubble sign on abdominal x-ray
 - (C) Loops of intestine in the left hemithorax on chest x-ray
 - (D) Gas in the walls of the intestine
 - (E) Donut sign on abdominal ultrasound
5. A 1-week-old male presents with intolerance of breastfeedings as well as several episodes of bilious vomiting. On physical exam, the patient's blood pressure and temperature are normal. The infant appears to be in pain. However, the abdomen does not appear to be distended, and there is no tenderness to palpation. Plain abdominal x-ray

shows an absence of gas within the bowel but is otherwise unremarkable. A complete blood count and electrolytes are normal. What is the next step in the management?

- (A) Admit for observation
- (B) Discharge patient and offer parents reassurance
- (C) Exploratory laparotomy
- (D) Upper GI study with oral contrast
- (E) Abdominal ultrasound

6. A male infant is born via normal spontaneous vaginal delivery at 39-weeks' gestation to a 32-year-old G1P1. She had good prenatal care. The infant is heard grunting while trying to breathe, and he shows bilateral subcostal and intercostal retractions. The patient is observed closely for several hours following delivery, and his respiratory status improves over that time. Which of the following is the most likely explanation of this patient's course?
- (A) Spontaneous reduction of congenital diaphragmatic hernia
 - (B) Closure of the ductus arteriosus
 - (C) Resorption of excess pulmonary fluid
 - (D) Paramyxovirus infection
 - (E) Closure of the foramen ovale
7. A 5-week-old boy presents with a 6-day history of vomiting. The parents report that his vomiting is more forceful than his usual spit ups and contain significantly more volume. The mother describes the vomit as partially digested milk. Between episodes of vomiting, the baby feeds vigorously. The parents report that he has made only one wet diaper today. On physical exam, the baby appears lethargic. Mucous membranes are dry, and the anterior fontanelle is open and sunken. Capillary refill is 2 s. The growth chart reveals a 0.5-lb weight loss since his clinic visit 7 days ago. What is the next step in management?
- (A) Surgical intervention
 - (B) CT of the abdomen
 - (C) Upper GI contrast study
 - (D) Fluid resuscitation
 - (E) Ultrasound
8. A 2-week-old infant delivered at 35-weeks' gestation is brought to the pediatrician by his mother who reports that he has had a harsh, barking cough and makes a high-pitched whistling sound when he inhales. He has been feeding poorly but has not had a fever. The mother also says that the patient has bouts of blue discoloration around his lips, more frequently when he is lying on his back than on his stomach. Chest x-ray is normal. What is the most likely diagnosis?
- (A) Foreign body aspiration
 - (B) Asthma
 - (C) Transient tachypnea of the newborn
 - (D) Tracheomalacia
 - (E) Congenital diaphragmatic hernia
9. A 2-h-old male infant born at 39-weeks' gestation is noted to be drooling. Prenatal ultrasound demonstrated polyhydramnios. Attempts at placement of an orogastric tube are unsuccessful as the tube only passes about 10 cm from the lips. What is the most important immediate concern for an infant with this condition?
- (A) Prevention of aspiration
 - (B) Nutrition
 - (C) Urgent surgical exploration
 - (D) Establishing positive pressure ventilation
 - (E) Confirmatory contrast esophagram

10. Which of the following is the next best step in the management of a 1-week-old infant born at full term with bilious emesis?
- (A) Abdominal ultrasound
 - (B) Broad-spectrum antibiotics and blood cultures
 - (C) Immediate operative repair
 - (D) Contrast enema
 - (E) IV fluids and nasogastric tube placement
11. A newborn male is found to have the majority of his small bowel eviscerated through an abdominal wall defect. The umbilicus appears to be intact. There is no membrane covering the bowel. The most important immediate risk to an infant with this condition is related to:
- (A) Sepsis
 - (B) Respiratory compromise
 - (C) Cardiac anomalies
 - (D) Dehydration
 - (E) Urinary obstruction
12. A 4-week-old boy presents with a 3-day history of forceful vomiting. The mother states that the vomitus only contains partially digested milk. She notes that the infant seems very hungry between feedings and drinks vigorously. Past history is significant for a skin infection for which the infant received oral erythromycin. On examination, the infant appears to be healthy appearing and in no acute distress. The physician feels there may be a small palpable mass in the right upper quadrant but is not certain. Electrolytes are normal. What is the best way to establish the most likely diagnosis?
- (A) Plain abdominal x-rays
 - (B) Laparoscopy
 - (C) CT of the abdomen
 - (D) Upper GI study with contrast
 - (E) Ultrasound
13. A 2-day-old male infant was diagnosed prenatally with trisomy 21. Delivery was uneventful, but pregnancy was complicated by polyhydramnios. The infant has had several episodes of bilious vomiting after breastfeeding but is otherwise stable. Which of the following would be the most likely finding on further work-up?
- (A) Dilated loops of small bowel with air-fluid levels on abdominal x-ray
 - (B) Inability to pass a nasogastric tube
 - (C) Abdominal distention with erythema of the overlying skin
 - (D) Two large air bubbles on abdominal x-ray
 - (E) Narrowing of the distal rectum on GI contrast study
14. A 12-day-old male born at 33 weeks becomes lethargic and hypothermic over the course of 24-h. He is not tolerating his formula feeds, has two episodes of bilious emesis, and has three episodes of bloody diarrhea. Physical exam reveals abdominal distention, visible loops of bowel, abdominal wall erythema, and absent bowel sounds. What is the most likely diagnosis?
- (A) Hirschsprung's disease
 - (B) Duodenal atresia
 - (C) Esophageal atresia with tracheoesophageal fistula
 - (D) Necrotizing enterocolitis
 - (E) Meconium ileus

15. A newborn female infant is born to a 19-year-old G1P0 mother who smokes. On physical exam, the small bowel is eviscerated through an abdominal wall defect to the right of the umbilicus. The small bowel appears matted and dilated. The infant appears to otherwise be healthy. Which of the following would have been expected in prenatal screening?
- (A) Elevated b-hCG
 - (B) Decreased estradiol
 - (C) Elevated alpha-fetoprotein (AFP)
 - (D) Oligohydramnios
 - (E) None of the above
16. A 4-month-old baby girl is seen at her pediatrician's office for her well-child check. The parents raise a concern that she has been vomiting approximately one-third of her meals since 2 weeks of age. The emesis is the color of milk and is not bile-stained. There has been no change in the frequency or amount of emesis. She is exclusively breastfed. On physical exam, mucous membranes are moist, and the anterior fontanelle is open and flat. Her growth is at the 75th percentile for height and weight and has not changed significantly since birth. She is otherwise asymptomatic and without findings on physical examination. Which of the following is the most likely diagnosis?
- (A) Tracheoesophageal fistula
 - (B) Duodenal atresia
 - (C) Pyloric stenosis
 - (D) Gastroesophageal reflux
 - (E) Malrotation
17. A 6-h-old male infant is noted to be dyspneic with an oxygen saturation of 86%. Physical exam reveals subcostal retractions and moderate perioral cyanosis. Which finding on chest x-ray would be most suggestive of a nonsurgical diagnosis?
- (A) Loops of bowel in the left chest
 - (B) Tip of orogastric tube located above carina
 - (C) Diffuse pulmonary interstitial edema
 - (D) Boot-shaped heart with upturned apex
 - (E) Double-bubble sign just beneath the diaphragm

Answers

1. Answer A
Laboratory evaluation in a patient with pyloric stenosis classically shows a hypochloric metabolic alkalosis (B–E). Chloride is typically lost in the gastric secretions (HCl) via vomiting. Alkalosis is caused by both a loss of protons (HCl) in the gastric fluid as well as secondary to a contraction alkalosis mediated by aldosterone secretion in the setting of hypovolemia. Hypokalemia is a late finding seen in infants who have been vomiting for prolonged period of time, also from contraction alkalosis. The infants also may have a paradoxical aciduria (acidic urine despite alkalosis). Initially, Na^+ in the renal tubule is reabsorbed in exchange for K^+ ions, but as K^+ levels decrease, Na^+ is instead exchanged for H^+ ions. The presentation of adrenal crisis in an infant may mimic that of pyloric stenosis. However, infants with adrenal crisis typically have hyperkalemic acidosis rather than the hypokalemic alkalosis that is typical of pyloric stenosis.
2. Answer A
Worsening respiratory status with feeding is suggestive of an anatomic or physiologic defect of the upper aerodigestive tract. The next step is to attempt to place an orogastric (OG) tube and perform anteroposterior and lateral chest x-rays. Failure to pass an OG tube with radiologic confirmation that the tube is in the upper esophagus is suggestive of esophageal atresia. An olive-shaped mass palpable in the epigastrium suggests a diagnosis of pyloric stenosis (B). Dyspnea that resolves over the first 24-h of life,

especially in a full-term neonate who is otherwise healthy, is likely transient tachypnea of the newborn, which is benign and self-limited (C). Loops of small bowel in the left hemithorax suggest a congenital diaphragmatic hernia, as does a scaphoid abdomen (it indicates that bowel contents are elsewhere such as in the chest) (D–E).

- ✓ 3. Answer E
Esophageal anastomotic stricture is a very common long-term complication of esophageal atresia with or without tracheoesophageal fistula repair. These cases may be treated with esophagoscopy with balloon dilation. There is no evidence given to suggest the patient has scleroderma, which is particularly unusual to present at age 10 (A). The patient likely does have gastroesophageal reflux, as this is another typical side effect of surgical repair, but the symptoms described are more likely attributable to esophageal stricture (B). Esophageal leak is more commonly a short-term complication, and many leaks will heal spontaneously (D). Finally, the patient is at increased risk for esophageal cancer, but this would be unlikely to develop so early in life (C).
- ✓ 4. Answer D
This patient likely has necrotizing enterocolitis (NEC), which most commonly affects premature infants. It causes necrosis of segments of intestine. In the necrotic segments, gas may be found within the walls of the intestine, a finding known as pneumatosis intestinalis. A palpable olive-shaped mass in the epigastric region suggests pyloric stenosis, which would present with non-bilious emesis, but not severe systemic illness (A). Double-bubble sign on abdominal x-ray suggests duodenal atresia, which would also not present so acutely (B). Loops of the intestine in the left hemithorax on chest x-ray suggest congenital diaphragmatic hernia, which may present with respiratory difficulty (C). Donut sign on abdominal ultrasound arises from intussusception of intestine, wherein one segment telescopes into another (E). This may occur at the ileocecal junction or at the site of a diverticulum and is a surgical emergency. However, it would not necessarily present as acute systemic illness.
- ✓ 5. Answer D
Bilious vomiting in an infant should always raise suspicion for midgut volvulus (a complication of malrotation) which left untreated can lead to intestinal gangrene. The physical exam may be benign, with no fever or abdominal tenderness as only the visceral peritoneum is initially affected. The patient may also have normal laboratory values. Similarly, plain abdominal x-ray may be normal. By the time the infant has evidence of systemic inflammation or peritonitis, there is a high likelihood that there is gangrenous bowel. The gangrene may involve the entire small bowel, and the patient may be subject to lifelong intravenous parenteral nutrition or may require small bowel transplantation. Thus, further work-up is always required to rule out this potentially devastating problem (A–B). Given the paucity of findings, it would be premature to take this infant directly to the operating room (C). Ultrasound is useful for pyloric stenosis (non-bilious vomiting) but not for midgut volvulus (E). Upper GI study with oral contrast is the best test as it will confirm failure of passage of the contrast, confirming a bowel obstruction, or show a malrotation. A normal study should demonstrate the normal C loop of the duodenum and show that the duodenal jejunal junction is to the left of the spine (crosses midline).
- ✓ 6. Answer C
The patient described above is an otherwise healthy, full-term newborn whose mother had good prenatal care. Furthermore, his respiratory status improved in the hours after delivery. Therefore, the most likely diagnosis is *transient tachypnea of the newborn*, which resolves as excess pulmonary fluid is resorbed. Spontaneous reduction of congenital diaphragmatic hernia is very unlikely (A). Closure of the ductus arteriosus or foramen ovale will have no effect on respiratory status in healthy patients (B, E). In patients with some cyanotic heart lesions, such as transposition of the great arteries (wherein the right ventricle ejects into the aorta and the left ventricle ejects into the pulmonary

artery), closure of the ductus arteriosus or foramen ovale will have an adverse effect on blood oxygenation. Paramyxovirus can lead to croup, which can lead to respiratory difficulty, but this diagnosis is unlikely given the patient's presentation (D).

✓ 7. Answer D

The presentation is classic for pyloric stenosis. Although the management of pyloric stenosis is surgical, the first priority in these infants is rehydration. The infant is presenting with signs of moderate to severe dehydration including dry mucous membranes, a sunken fontanelle, delayed capillary refill, and decrease urinary output. The course warrants fluid resuscitation prior to any diagnostic work-up or consultations. After fluid resuscitation, the gold standard imaging modality is ultrasound to assess for pyloric stenosis (E). Only if ultrasound is negative or equivocal is an upper GI obtained (C). If imaging modalities demonstrate pyloric stenosis, surgical consultation is then obtained (A). CT of the abdomen is not warranted in the work-up of suspected pyloric stenosis (B).

✓ 8. Answer D

Softness of the tracheal cartilage is known as *tracheomalacia*. Because the cartilaginous support is soft and flexible, the airway can collapse. The condition is usually worse when the patient is supine because gravity pulls the anterior trachea downward toward the posterior trachea, thereby occluding the upper airway. Foreign body aspiration (such as a toy or food particles) would present similarly, but this is unlikely in a 2-week-old (A). Asthma is also a consideration, but tracheomalacia should be ruled out first (B). Transient tachypnea of the newborn usually resolves within 1–2 days after delivery (C). Congenital diaphragmatic hernia generally presents at birth (E). Delayed presentations rarely do occur, but the chest x-ray would show loops of the bowel, or part of the liver, in the thorax.

✓ 9. Answer A

Based on the classic history of polyhydramnios and excessive drooling in a newborn, the patient likely has esophageal atresia. The most important concern is prevention of aspiration. Nutrition can be established after early surgical repair or via a gastrostomy tube if surgery is not undertaken (as in cases where the infant is premature or has pneumonia from aspiration) (B). Urgent surgical exploration is not indicated, as surgery may be delayed in some patients (C). Positive pressure ventilation may distend the stomach and cause aspiration (D). Therefore, it should be avoided when possible. Contrast esophagram is only performed if chest x-ray is nondiagnostic or if the location of the fistula cannot be identified (E). This study carries risk of aspiration pneumonia from the contrast agent.

✓ 10. Answer E

The first steps in treating a patient with bilious emesis are fluid resuscitation and gastrointestinal decompression with a nasogastric (NG) tube. Once the IV fluid resuscitation has begun, the patient may undergo an upper GI study to evaluate for evidence of midgut volvulus, which may present with distended proximal bowel and a paucity of gas in the distal bowel. Abdominal ultrasound is used in suspected cases of pyloric stenosis (A). Broad-spectrum antibiotics are not indicated as there is no evidence of infection (B). Operative repair cannot occur until the patient has been stabilized and a diagnosis has been confirmed (C). Contrast enema would be used to evaluate for Hirschsprung's disease, which would present as failure to pass meconium and not necessarily bilious emesis (D).

✓ 11. Answer D

This patient has gastroschisis. Since the intestines are outside of the abdominal cavity, insensible fluid losses will be much greater than in an infant without gastroschisis. Therefore, covering of the exposed intestine with moist gauze and IV fluid resuscitation are critical first steps in management. Such patients are also at risk of hypother-

mia. While exposed intra-abdominal contents increase risk of infection and sepsis, this is not as immediate of a concern as is dehydration (A). After operative repair, patients may be paralyzed to allow the abdominal wall to relax and stretch to accommodate the intestines. If the abdominal cavity is not sufficiently large to accommodate the bowel, the bowel is covered with a silo temporarily. Attempting to forcefully reduce all the small bowels and close it under tension will result in abdominal compartment syndrome, bowel ischemia, and respiratory compromise (B). Cardiac anomalies are more of a concern in patients with omphalocele than gastroschisis, but regardless this is not an immediate concern (C). Urinary obstruction is not a typical feature of gastroschisis, though it could rarely occur if the bladder were also herniated through the abdominal wall (E).

✓ 12. Answer E

Ultrasound is the image modality of choice in diagnosing pyloric stenosis, as it does not require any radiation exposure. If ultrasound is negative or equivocal and pyloric stenosis is highly suspected, diagnosis may be attempted with a barium upper GI study with contrast. Upper GI was the test of choice prior to the advent of ultrasound (D). However, it must be done carefully as it risks causing aspiration given that the infant has a gastric outlet obstruction. Typical findings include elongated pyloric canal (string sign) and delayed gastric emptying. In addition, upper GI studies are further helpful in the setting of a negative ultrasound in order to assess for other items on the differential diagnosis, particularly gastroesophageal reflux. Reassurance would be inappropriate if pyloric stenosis is highly suspected (A). Operative intervention with pylorotomy would be the definitive treatment should the child be diagnosed with pyloric stenosis, but confirmatory testing should be undertaken first (B). CT of the abdomen is not an imaging modality of choice for diagnosing pyloric stenosis (C).

✓ 13. Answer D

Given the history of polyhydramnios, bilious emesis, and Trisomy-21, the most likely diagnosis is duodenal atresia. Because of the duodenal obstruction, there would be no gas in the small bowel. Air-fluid levels on abdominal x-ray are characteristic of more distal intestinal obstruction (A). Inability to pass a nasogastric tube is suggestive of choanal atresia (B). Abdominal distention with erythema of the overlying skin is concerning for necrotizing enterocolitis (C). Narrowing of the distal rectum on GI contrast study is found in Hirschsprung's disease (E).

✓ 14. Answer D

In a premature neonate with rather sudden systemic illness, feeding intolerance, and bloody stools, necrotizing enterocolitis would be the most likely diagnosis. Visible loops of distended bowel and abdominal wall erythema are additional classic findings. Initial treatment is to place the infant NPO, stomach decompression, and administration of IV antibiotics. Surgical management is indicated for suspected perforation, as evidenced by free intraperitoneal air or progressive clinical deterioration (rising WBC count, falling platelet count, worsening acidosis). Hirschsprung's disease would present with failure to pass stool at birth and not a sudden decompensation (A). Duodenal atresia presents with bilious vomiting, but due to the atresia, it presents at birth and with failure to pass meconium (B). Esophageal atresia with tracheoesophageal fistula would present with respiratory distress during feeding (D). Meconium ileus classically would present with failure to pass meconium at birth and raises concern for cystic fibrosis (E).

✓ 15. Answer C

Eviscerated bowel without a membrane covering it, with the abdominal wall defect to the right of the umbilicus, is termed gastroschisis. It is more common in young mothers and in those who smoke during pregnancy. Maternal serum AFP tends to be elevated in cases of abdominal wall defects, including both gastroschisis and omphalocele (evisceration through the umbilicus and with a membrane covering bowel).

Typically, maternal serum AFP is greater in gastroschisis than in omphalocele. Maternal serum AFP is checked as part of the triple screen or quad screen that is performed. Elevated maternal serum AFP is seen in other conditions such as multiple gestation, neural tube defects, abruptio placentae, or endodermal sinus tumor, making this a nonspecific marker for abdominal wall defects. Gastroschisis is associated with intestinal atresia. Since the fetus may be unable to swallow amniotic fluid, it is associated with polyhydramnios.

✓ 16. Answer D

Gastroesophageal reflux is a common complaint in infants less than 1 year of age. In the first year of age, the pylorus is not fully developed and therefore not fully functional, leading to occasional episodes of reflux (also called spitting up). Gastroesophageal reflux *disease* (GERD) is not diagnosed until the infant is failing to gain weight. Treatment of GERD includes thickening the feeds, keeping the infant upright after feeds, and feeding smaller amounts at shorter intervals. Tracheoesophageal fistula typically presents at birth with inability to control secretions. A rare "H" type (fistula without esophageal atresia) often presents in a delayed fashion but would present with recurrent respiratory infections from aspiration and not vomiting (A). Duodenal atresia would present as bilious vomiting in the newborn period and the classic "double-bubble" sign on abdominal x-ray (B). Pyloric stenosis presents with non-bilious, projectile vomiting in the first few weeks of life and typically not at 4 months of age (C). In addition, it would progressively worsen with time. Malrotation would present with abdominal distension and bilious vomiting (E).

✓ 17. Answer C

Diffuse pulmonary interstitial and/or alveolar edema suggests transient tachypnea of the newborn, which is self-limited and resolves within 1–2 days. Loops of bowel in the left chest suggest a congenital diaphragmatic hernia (A). An orogastric tube that does not pass beyond the proximal esophagus suggests an esophageal atresia (B). Boot-shaped heart with upturned apex is found in infants with tetralogy of Fallot, a constellation of congenital cardiac anomalies, that specifically includes ventricular septal defect, pulmonary stenosis, large overriding aorta, and right ventricular hypertrophy (D). The double-bubble sign is found in duodenal atresia (E).

Surgical Complications

Jeffry Nahmias

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Postoperative Bleeding

*Areg Grigorian, Christian de Virgilio, Dennis Y. Kim,
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Case Study

A 50-year-old male is scheduled to undergo an elective inguinal hernia repair. He has noted pain in the hernia, which is reducible, for the past year. His past history is significant for hypercholesterolemia and mild hypertension. He has had no prior surgery. He does not smoke and only drinks occasionally. Family history is positive for coronary artery disease. He takes aspirin and a statin. He takes no herbal

remedies. Otherwise, he has no significant medical history. On physical examination, he has no stigmata of portal hypertension or cirrhosis. Intraoperatively, the patient is noted to have diffuse oozing from all tissues in the operative field. Despite attempts at complete hemostasis, the patient develops a postoperative hematoma which requires evacuation on postoperative day 2. Laboratory values

include a normal chemistry panel, normal hemoglobin and hematocrit, a platelet count of 250,000 cells/ml (normal 140,000–450,000 cells/ml), INR of 1.0, and a PTT of 45 seconds (normal 18–28 seconds). On further questioning, he reports a history of excessive bleeding when he had a wisdom tooth extracted 20 years ago.

Diagnosis

What Is the Differential Diagnosis of Bleeding in the Postoperative Setting?

Table 39.1

Condition	Comments
<i>Surgical bleeding</i>	Bleeding from a major artery or vein that was missed during surgery must be ruled out first, especially in the immediate postoperative period
<i>Medications</i>	Inquire about aspirin, clopidogrel, heparin, warfarin, or any other antiplatelet or anticoagulant medication and some herbal remedies
<i>Inherited coagulation disorders</i>	Patients with von Willebrand disease may have a history of excessive bleeding after minor procedures or very heavy menses; hemophilia A and B usually present in childhood with spontaneous hemorrhage into joints (hemarthrosis)
<i>Liver disease</i>	Reduced production of clotting factors
<i>Renal failure</i>	Uremia impairs platelet function
<i>DIC</i>	Seen with severe sepsis, malignancy, and childbirth complications; leads to bleeding and microthrombi; manifests with diffuse bleeding from wounds and surgical sites, hematemesis, digital cyanosis, renal insufficiency, and stroke
<i>The bloody vicious cycle ("lethal triad of death")</i>	Refers to three factors (hypothermia, acidosis, coagulopathy) that work in concert: more common after long operations, trauma, emergency general surgery, and following large volume of room temperature IV fluids and in those who have suffered significant bleeding

DIC disseminated intravascular coagulation

What Is the Most Likely Cause of the Bleeding in the Patient Described Above?

The bleeding is likely a medical bleed and not a surgical one. The finding of diffuse oozing at the time of operation together with a prolonged PTT would suggest an underlying bleeding diathesis.

What Is the Differential Diagnosis for Prolonged PTT and the Common Features?

Table 39.2

Condition	PT	PTT	BT	Acquired/ congenital	Comments
<i>Acquired factor VIII inhibitors</i>	—	↑	—	Acquired	Occurs in postpartum patients, rheumatic disease, and malignancy; presents with purpura, hemarthroses, and soft tissue bleeding
<i>Antiphospholipid syndrome (SLE)^a</i>	—	↑	—	Acquired	Young woman with malar rash, arthritis, photosensitivity, renal/cardiac symptoms, fevers, malaise, and recurrent 1st trimester pregnancy loss; associated with lupus
<i>Hemophilia A</i>	—	↑	—	Congenital	X-linked recessive, factor VIII deficiency, males, present early in childhood with spontaneous bleeding in joints (hemarthroses) or life-threatening hemorrhage following minor trauma
<i>Hemophilia B</i>	—	↑	—	Congenital	Same as hemophilia A but factor IX deficiency
<i>Heparin administration</i>	—	↑	—	Acquired	Postoperative prophylaxis for DVT and PE, decreases post-MI thrombus risk
<i>von Willebrand disease</i>	—	—/↑	↑	Both	Bleeding after minor surgical procedure or history of excessive menses

BT bleeding time, DVT deep vein thrombosis, PE pulmonary embolism, MI myocardial infarction, PT prothrombin time, PTT partial thromboplastin time, SLE systemic lupus erythematosus

^aAntiphospholipid syndrome is a hypercoagulable state

What Is the Most Likely Diagnosis?

The above patient has an isolated prolonged PTT. Antiphospholipid syndrome associated with SLE is paradoxically a *hypercoagulable* state as opposed to causing bleeding. An acquired antibody to factor VIII (acquired hemophilia) is rare and is most commonly associated with postpartum patients, rheumatic disease, and cancer. Hemophilia A and B are clinically indistinguishable. With severe factor deficiencies, they present early in childhood with spontaneous bleeding in the joints (hemarthrosis) or life-threatening hemorrhage following trauma. von Willebrand disease (vWD) is not associated with a history of severe bleeding but rather with bleeding after minor surgical procedures or a history of excessive menses. Thus, the most likely diagnosis is vWD.

History and Physical Examination

Why Is It Important to Ask About a History of Bleeding After Minor Trauma/Procedures?

A history of bleeding suggests a predisposition to bleeding risk. Important questions to ask include a family history of

bleeding disorders, history of excessive bleeding in the mouth, epistaxis, bleeding into the muscle and joints (hemarthrosis), excessive menstrual bleeding, liver or kidney disease, and excessive bleeding after minor procedures (dental extraction, skin biopsy).

Why Is It Important to Ask About a Family History of Bleeding?

A family history of bleeding suggests there may be an inherited bleeding disorder.

What Medical Conditions Are Risk Factors for Bleeding?

Liver and renal diseases, as well as nutritional deficiency, increase the risk of bleeding, the latter due to vitamin K deficiency. Malabsorption syndromes including short bowel syndrome and cystic fibrosis lead to vitamin K deficiency. Cardiac disease, by virtue of the various antiplatelet agents often prescribed (aspirin, clopidogrel, warfarin), increases the risk of bleeding.

Physiology/Pathophysiology

What Is the Difference Between Primary and Secondary Hemostasis Disorders?

Disorders of primary hemostasis are usually due to abnormalities in platelets, whereas disorders of secondary hemostasis are usually due to factor abnormalities. Platelet abnormalities can be divided into quantitative or qualitative disorders. After primary hemostasis, the coagulation cascade (■ Fig. 39.1) generates thrombin, which converts fibrinogen in the platelet plug to fibrin. The fibrin is then cross-linked by factor VIII to form a stable platelet-fibrin thrombus. Impairment in this cascade can lead to disorders of secondary hemostasis and is most often due to factor abnormalities.

What Is Coagulopathy?

This term is reserved for conditions that lead to an impairment of the body's ability to clot blood. Normal blood clotting involves as many as 20 different plasma proteins. When these proteins are missing or deficient, patients can present with

bleeding symptoms that can range from mild to severe. This can occur spontaneously or following minor trauma. Metabolic acidosis and hypothermia exacerbate coagulopathy.

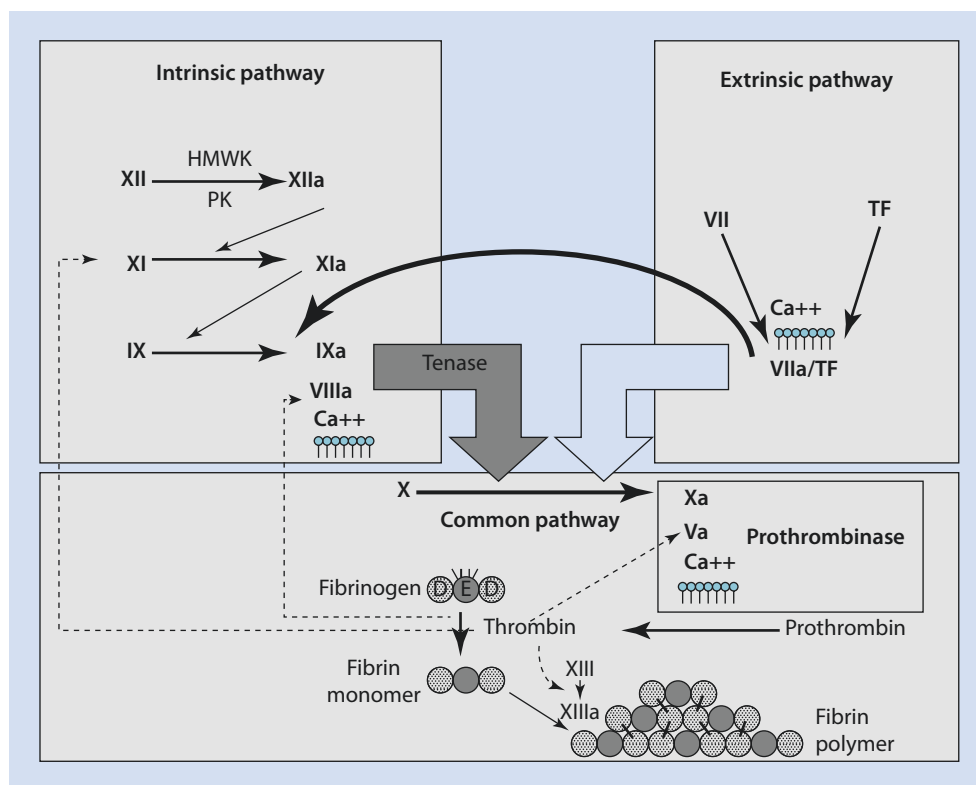
What Is Meant by a Medical Versus a Surgical Postoperative Bleed?

A surgical bleed refers to bleeding that should be corrected with surgery, for example, bleeding from a focal area (an artery or vein) that was inadequately ligated or sutured during the initial surgery. A medical bleed refers to diffuse bleeding caused by underlying coagulopathy. Since medical bleeding is diffuse and caused by a bleeding disorder, reoperation is not beneficial.

What Is the Pathophysiology of vWD? What Are the Subtypes?

von Willebrand factor (vWF) is a protein needed to form a platelet plug. When vascular tissue is damaged, the exposed subendothelial collagen is able to bind to vWF. Platelets can

■ **Fig. 39.1** Coagulation cascade. *HMWK* high molecular weight kininogen, *PK* prekallikrein, *TF* tissue factor. (From: Kottke-Marchant K. *Contemporary cardiology: antithrombotic drug therapy in cardiovascular disease*, The Role of Coagulation in Arterial and Venous Thrombosis. © Humana Press, a part of Springer Science+Business Media, LLC 2010, reprinted with permission)



■ **Table 39.3** Subtypes of vWD

Type	Inheritance	Quantitative or qualitative	Features
1	AD	Quantitative	The most common overall, often has mild symptoms
2	AD	Both	Contains four subtypes of which type 2A is most common, often has moderate symptoms
3	AR	Quantitative	Rare, causes the most severe symptoms

AD autosomal dominant, *AR* autosomal recessive

then bind to vWF using the GPIb receptor to ultimately form the platelet plug and thus complete primary hemostasis. vWD is most commonly congenital but can be acquired. The congenital form has three subtypes (■ Table 39.3) causing both qualitative and quantitative defects. Since vWF is also a cofactor for factor VIII, severely decreased levels of vWF can lead to abnormally prolonged PTT, depending on the degree of activity reduction of factor VIII.

How Does Renal Failure Cause Coagulopathy?

End-stage renal disease results in uremic toxins circulating in the blood, which cause platelet dysfunction. This can initially be managed with the administration of desmopressin and/or hemodialysis.

How Does Liver Disease Cause Coagulopathy?

As liver disease worsens, so does the synthetic function of the liver manifested by a prolonged PT and increased INR. The majority of patients have thrombocytopenia and decreased

production of coagulation factors. The thrombocytopenia is caused by a combination of increased sequestration in the spleen, deficiency of thrombopoietin, and immune-mediated destruction of platelets.

Watch Out

Factor VIII is the only component of the clotting cascade not exclusively synthesized by the liver and remains at a normal (or higher) level during liver failure; all the other factor levels will decrease.

What Are the Vitamin K-Dependent Clotting Factors?

Factors II, VII, IX, and X, protein C, and protein S.

How Is Thrombocytopenia Defined? How Do Various Platelet Count Thresholds Affect Bleeding?

Thrombocytopenia is defined by a decreased number of platelets (<150,000/uL) leading to increased risk of bleeding. The clinical severity of thrombocytopenia has an inverse relationship with the platelet count (■ Table 39.4).

■ **Table 39.4** Thrombocytopenia presentation based on platelet count

Laboratory finding	Clinical presentation
Platelets >100,000 cells/mL	Asymptomatic
Platelets 50,000 to 100,000 cells/mL	Occasional petechiae, 50,000 cells/mL is minimum to proceed with surgery
Platelets 10,000 to 50,000 cells/mL	Purpura after minor trauma
Platelets <10,000 cells/mL	Spontaneous intracerebral hemorrhage and bruising, bleeding gums

What Are the Causes for Thrombocytopenia?

■ **Table 39.5**

Etiology	Pathology	Labs	Management
<i>Impaired production</i>	Abnormal/reduced platelet precursor caused by drugs, infection, alcohol, mineral deficiency, malignancy	Bone marrow biopsy shows ↓ megakaryocytes	Stop offending agent, replete deficiencies, treat underlying disorder
<i>Platelet pooling</i>	Splenic platelet sequestration		If symptomatic, splenectomy may be required

(continued)

Table 39.5 (continued)

Etiology	Pathology	Labs	Management
<i>HIT</i>	Heparin forms complex with platelet factor 4 → produces IgG antibodies which destroy platelets; remnants activate remaining platelets → thrombus	Sudden decrease in platelet count >50%; typically, 5–10 days after administration of heparin	Stop heparin, switch to direct thrombin inhibitor such as dabigatran
<i>ITP</i>	Autoimmune production of IgG leading to platelet destruction	Platelets commonly <50,000	<i>Children</i> : observe for spontaneous resolution, corticosteroids, and IVIG <i>Adults</i> : corticosteroids, IVIG, and splenectomy
<i>TTP</i>	Platelets are consumed in the formation of microthrombi in small vessels, due to an enzyme deficiency (ADAMTS13) that normally cleaves vWF multimers	↑ reticulocytes, blood smear shows evidence of hemolytic anemia (schistocytes)	Emergent plasmapheresis, corticosteroids, and splenectomy
<i>DIC</i>	Initial coagulopathy with widespread clot formation that quickly evolves to a state of pathologic consumption of platelets and coagulation factors	↑ INR, ↑ PTT, ↓ fibrinogen, ↑ fibrinogen split products, ↑ D-dimer, ↓ hemoglobin, ↓ hematocrit	Treat underlying disorder, platelets, FFP, and cryoprecipitate
<i>HELLP syndrome</i>	Pathogenesis unclear, sequela of eclampsia, and may be associated with aberrant placental development	↑ LFTs, ↓ hemoglobin, ↓ haptoglobin, schistocytes on blood smear	Methyldopa to reduce blood pressure, corticosteroids to speed lung maturity, induce labor if >34 weeks

DIC disseminated intravascular coagulation, *HIT* heparin-induced thrombocytopenia, *ITP* idiopathic thrombocytopenic purpura, *IVIG* intravenous immunoglobulin, *FFP* fresh frozen plasma, *TTP* thrombotic thrombocytopenic purpura, *HELLP* hemolysis, elevated liver (enzymes), low platelets

Watch Out

Alcohol abuse is the most common cause of thrombocytopenia.

Watch Out

Although HIT leads to thrombocytopenia, it is considered a *hypercoagulable* state.

What Is the Mechanism of DIC?

The initial coagulopathy occurs because of extensive activation of the clotting cascade, often by the release of endothelial tissue factor. Uncontrolled clotting and subsequent fibrinolysis lead to a deficiency in clotting factors resulting in abnormal bleeding. Despite subsequent fibrinolysis, the patient with DIC may form diffuse microthrombi in addition to having abnormal bleeding. DIC has a poor prognosis without early treatment as the microthrombi can cause widespread infarcts. The common causes of DIC can be remembered with the mnemonic DIC: delivery, infection, and cancer (Table 39.6).

Watch Out

The primary treatment of DIC is to treat the underlying cause.

Table 39.6 Disseminated intravascular coagulation (DIC)

Etiology	Features
<i>Delivery</i>	Tissue thromboplastin in amniotic fluid activates the coagulation cascade
<i>Infection</i>	Sepsis can result in the induction of endothelial cells to make/release tissue factor; the most common mechanism involves TNF associated with gram-negative bacteria
<i>Cancer</i>	Auer rods in AML are potent activators of the coagulation cascade; mucin associated with adenocarcinoma can also activate the cascade

TNF tumor necrosis factor, *AML* acute myeloid leukemia

What Is Physiological Fibrinolysis?

Physiological fibrinolysis begins with the generation of fibrin and occurs when plasmin binds to it. It is associated with the breakdown of clots and is an essential component of the hemostatic system as it is required to limit the extent of clot formation, thus maintaining blood flow by keeping vasculature clear of thrombi.

Watch Out

Urine contains high levels of urokinase and tPA to prevent clots in the urinary system but can result in more bleeding after transurethral resection of the prostate.

What Can Abnormal Activation (Pathological) of the Fibrinolytic Pathway Cause? How Is It Classified?

This can result in bleeding and is associated with the presence of excess plasmin, which overwhelms the endogenous antiplasmin mechanisms leading to the consumption of coagulation factors and platelets, thus impairing the ability to form clots. Hyperfibrinolysis is further classified into primary and secondary. Primary hyperfibrinolysis results from an increase in circulating tissue plasminogen activator (tPA). Under normal conditions, tPA has low plasminogen activating capability that increases exponentially when bound to fibrin, thus limiting fibrinolysis until fibrin is generated by a preformed clot. During conditions where there is an excess amount of circulating tPA (i.e., decreased hepatic clearance, loss of antiplasmin mechanisms), there may be sufficient activity to increase plasmin generation without fibrin. Secondary fibrinolysis is a response to a systemic hyperco-

agulable state and increased amounts of fibrin. This most often occurs during a systemic inflammatory state, such as sepsis or DIC.

What Coagulation Factors Do INR and PTT Measure, and What Drug Therapies Can They Monitor?

Table 39.7

	Measures	Coagulation factors	Monitors
<i>INR</i>	Extrinsic and common coagulation pathways	I (fibrinogen), II (prothrombin), V, VII, X	Warfarin
<i>PTT</i>	Intrinsic and common coagulation pathways	I, II, V, VIII, IX, X, XI, XII	Heparin

Describe the Mechanism of the Commonly Used Anticoagulant Medications

Table 39.8

Medication	Mechanism of action	Reversible?
<i>Aspirin</i>	Irreversibly inhibits platelet cyclooxygenase enzymes, which results in decreased formation of PGE-2 and thromboxane-A ₂	No
<i>Clopidogrel</i>	Blocks ADP receptors to suppress fibrinogen binding to platelets and thus inhibits platelet aggregation	No
<i>GP-IIb/GP-IIIa inhibitors</i> (e.g., <i>abciximab</i>)	Inhibit platelet aggregation by binding to platelet GP-IIb/GP-IIIa receptors	No
<i>Heparin</i>	Activates antithrombin-III, activated antithrombin-III inactivates thrombin and factor Xa	Protamine sulfate
<i>LMWH</i> (e.g., <i>enoxaparin</i>)	Binds to factor Xa to prevent clot formation	Protamine sulfate
<i>Direct thrombin inhibitor</i> (e.g., <i>argatroban</i>)	Inhibits thrombin to suppress factor activity and decrease platelet aggregation	No; hemodialysis may help
<i>Warfarin</i>	Inhibits vitamin K epoxide reductase, an enzyme required for the production of factors II, VII, IX, and X	Prothrombin complex concentrate (rapid), fresh frozen plasma (slower), vitamin K (slowest)

LMWH low molecular weight heparin

Workup

Prior to an Elective Operation, What Is the Best Method to Identify a Patient at Risk for Bleeding During Surgery? Is Routine Laboratory Screening for Bleeding Disorders Necessary?

Clinical history remains the gold standard for preoperative assessment of hemostasis. Specifically, a history of excessive bleeding after minor procedures is important. In addition, in most cases, INR, PTT, and platelet count are ordered preoperatively. No additional routine screening for bleeding disorders is necessary.

Management

What Is the First Step in the Management of a Patient with Suspected Postoperative Bleeding?

Always start with the A (airway), B (breathing), and C (circulation) of resuscitation. Make sure the patient has adequate IV access and that baseline labs have been sent including a type and cross, complete blood count, INR, and PTT.

At What Point Should Re-exploration Be Considered for a Patient Who Is Bleeding Postoperatively?

Postoperative bleeding, particularly after abdominal surgery, is sometimes difficult to recognize, as there are no visible signs on physical exam (such as an expanding hematoma), and the surgeon presumably closed the abdomen with good hemostasis. Bleeding should always be suspected in a patient who develops unexplained or sustained hypotension after surgery. However, if the bleeding is thought to be a medical bleed, the general recommendation is to correct the underlying coagulation problem first as medical bleeds are unlikely

to be corrected with surgery, and then re-explore if the bleeding continues.

How Is Bleeding Secondary to Renal Failure Corrected?

Although desmopressin can initially be used (increase vWF), dialysis is considered the definitive management.

How Is Bleeding Secondary to Liver Disease Corrected?

Fresh frozen plasma, cryoprecipitate, coagulation factors, and platelet transfusion.

At What Threshold Should Platelets Be Administered?

The threshold for platelet transfusion remains controversial, but it is never recommended for platelet destructive processes (e.g., hemolytic uremic syndrome). For patients (bleeding or not) that will be undergoing an invasive procedure (e.g., surgery) and have platelet counts <50,000/ul, a prophylactic platelet transfusion is acceptable. For all asymptomatic patients with platelet counts <10,000/ul, a platelet transfusion is also given to prevent *spontaneous intracranial bleeding*.

What Is the Best Way to Urgently Reverse Warfarin?

Fresh frozen plasma was the traditionally correct answer. Newer agents include prothrombin complex concentrates (PCCs), which are available as a “4-factor” or “3-factor” formulation and have demonstrated ability to more rapidly reverse warfarin compared to fresh frozen plasma. Additionally, the smaller volume of PCC has the added benefit of not causing volume overload, especially in those patients with congestive heart failure or end-stage renal disease.

Complications

What Are the Different Types of Transfusion Reactions, Their Causes, and Management?

■ Table 39.9

Type	Timing	Pathology	Management
<i>Febrile nonhemolytic</i>	Minutes to hours after transfusion	The most common transfusion reaction; caused by cytokines from donor leukocytes	Self-limited, acetaminophen can help
<i>Acute hemolytic</i>	Within 24 hours of transfusion	ABO incompatibility leading to severe destruction of donor red blood cells by preformed host antibodies	Stop transfusion, IV fluids to induce diuresis
<i>Delayed hemolytic</i>	1–14 days after transfusion	Rh antibodies leading to the destruction of donor red blood cells, requires sensitization	Self-limited
<i>Anaphylactic</i>	Rapid and sudden onset	Shock results from anti-IgA antibodies, occurs in patients with selective-IgA deficiency	Stop transfusion, epinephrine, intubation, fluid resuscitation
<i>Allergic/urticarial</i>	Minutes to hours after transfusion	Results from the plasma present in donor blood	Diphenhydramine

Watch Out

An overlooked but common cause of fever in the first 6 hours after surgery is a febrile nonhemolytic transfusion reaction, if the patient received blood products during the case.

What Is the Leading Cause of Transfusion-Related Fatalities?

Transfusion-related acute lung injury (TRALI) is a serious blood transfusion complication characterized by non-cardiogenic pulmonary edema. Although the incidence has decreased, it remains the leading cause of transfusion-related fatalities. The underlying mechanism has still not been elucidated but is thought to involve donor antibodies attacking the recipient's white blood cells (WBCs). The antibody-WBC complex aggregates in the vasculature of the lungs leading to the release of inflammatory mediators which increase the permeability of the lung capillaries and thus lead to pulmonary edema. Fluid resuscitation and vasopressors are often required. Aggressive respiratory support is needed in the majority of cases.

Areas You Can Get in Trouble

Failing to Stop Antiplatelets/Anticoagulants in a Timely Fashion Prior to Surgery

Platelet aggregation recovers within 4 days of stopping aspirin, but clopidogrel must be stopped for 7 days to achieve a normal platelet aggregation response. After stopping warfarin, it usually takes 2–3 days for the INR to fall below 2.0 and 4–6 days for the INR to normalize. Once the INR is 1.5 or below, surgery can be performed with relative safety in most cases.

Rebound Hypercoagulability

Recent studies indicate that sudden cessation of aspirin and anticoagulants in long-term users may lead to a rebound hypercoagulability. Thus, risk of bleeding during surgery must be weighed against the potential increased risk of thromboembolic events. In the case of carotid artery surgery, aspirin is always continued.

Summary of Essentials

History and Physical Examination

- Surgical bleeds result from inadequate hemostasis and may require reoperation.
- Risk factors for coagulopathy: copious IV fluids or transfusions, hypothermia, metabolic acidosis, liver or kidney disease, DIC, family history of bleeding, and anticoagulant/antiplatelet medications.
- Beware of HIT in patients who have recently begun heparin therapy.

Workup

- The most important diagnostic modality for coagulopathy is a clinical history.
- Warfarin is monitored with INR; heparin is monitored with PTT.
- Always check for signs of liver and kidney dysfunction.

Management

- The treatments of uremic coagulopathy are desmopressin (acutely) and hemodialysis (more definitively).

- The treatment of hepatic coagulopathy is FFP.
- Heparin can be reversed with protamine; warfarin can be reversed with PCC rapidly.
- For most elective procedures, platelets >50,000/ul are sufficient.

Complications

- TRALI is treated with IV fluids, vasopressors, and respiratory support.

Suggested Reading

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Postoperative Decreased Urine Output

Dean Spencer, Dennis Y. Kim, Christian de Virgilio, Areg Grigorian, and Jeffry Nahmias

Case Study

A previously healthy 65-year-old female underwent an emergent sigmoid colectomy and proximal colostomy for perforated diverticulitis. Intraoperatively, the patient was found to have extensive fecal contamination of the peritoneal cavity with minimal blood loss. She received 2 liters of intravenous fluids during the operation. Twelve hours after

surgery, the patient is found to have a blood pressure of 110/60 mmHg (supine), heart rate of 110/min, temperature of 37.8 °C, and respiratory rate of 14/min. Her mucous membranes appear dry and skin turgor is decreased. She does not have jugular venous distention, and her cardiac and respiratory exams are unremarkable. The patient is noted to have only produced

30 cc of dark yellow urine in the last 3 hours. Postoperative laboratory values demonstrate an increasing BUN of 34 mg/dl (normal 7–21 mg/dl) and a creatinine of 1.5 mg/dl (0.5–1.4 mg/dl) (preoperative creatinine 0.8 mg/dl). Hemoglobin and hematocrit are the same as preoperative at 11 g/dl (12–15.2 g/dl) and 33% (37–46%).

Diagnosis

What Is the Differential Diagnosis for a Rise in Creatinine in the Postoperative Setting?

Table 40.1

Type	Causes	Pathophysiology
Prerenal	Hypovolemia (postsurgical bleeding, dehydration), decreased cardiac output (heart failure)	Inadequate perfusion of a normal functioning kidney
Intrinsic/renal	Acute tubular necrosis (ATN) (e.g., renal artery occlusion; drugs: radiocontrast agents, aminoglycosides; rhabdomyolysis); interstitial nephritis (penicillin, cephalosporins, sulfa drugs, NSAIDs)	Prolonged ischemia of the kidney or toxins leading to parenchymal injury
Postrenal	Obstruction of urine, benign prostate hypertrophy (BPH), prostate cancer, nephrolithiasis, bilateral ureteral ligation, urethral stricture	Increased nephron tubular pressure

History and Physical Exam

Why Is It Important to Review the Operative Record and the Anesthetic Record?

It is useful to review the operative and anesthetic record to look for any events that may be contributing to decreased urine output. For example, in patients who appear to be hypovolemic, checking the record for their estimated intraoperative blood loss, complications during the surgery that may increase suspicion for potential sites of postoperative bleeding, the administration of anticoagulants, the requirement of pressors or blood products, and the amount of fluids received is essential in discovering the etiology.

What Is the Most Common Presentation of AKI?

The most common presentation of AKI is prerenal azotemia. Most patients are asymptomatic and present with only a rise in BUN and creatinine (azotemia) with a ratio >20:1. The earliest sign of AKI is oliguria (please see below).

What Is the Most Likely Cause for the Patient's Decreased Urine Output?

The most likely cause for the patient's decreased urine output is prerenal acute kidney injury (AKI) secondary to hypovolemia. Volume depletion and third space losses are common following surgery, particularly in the setting of significant peritoneal inflammation. The patient is oliguric with tachycardia and physical exam findings consistent with volume depletion (dry mucous membranes and decreased skin turgor). There has also been an acute increase in her serum BUN and creatinine (>20:1) which is consistent with prerenal AKI.

What Is the Difference Between Oliguria and Anuria?

The normal urine output for an adult is 0.5–1.0 ml/kg/hour. For children, normal urine output is 1.0–2.0 ml/kg/hour. Oliguria describes decreased but not absent urine output and is defined as a urine output less than 0.5 ml/kg/hour for two consecutive hours. When urine output becomes less than 50–100 ml over a 24-hour period, the patient is considered to be anuric. Producing absolutely no urine is unusual and may be a result of a technical error, especially in patients with a urinary catheter in place (clogged or kinked catheter).

What Are the Most Common Nephrotoxic Medications?

The most common nephrotoxic medications are intravenous contrast agents (contrast-induced nephropathy), aminoglycosides (e.g., gentamicin), amphotericin, cisplatin, cyclosporine, and nonsteroidal anti-inflammatory drugs (NSAIDs).

Physiology/Pathophysiology

Which Patients Are at Greatest Risk for Intravenous Contrast-Induced AKI?

Patients with preexisting renal damage (e.g., glomerulonephritis, diabetes) are at greatest risk. Contrast-induced nephropathy is widely defined as an absolute increase in serum creatinine of 0.5 mg/dl or a relative increase of 25% from the baseline value, assessed 48–72 hours following intravascular administration of contrast media.

Watch Out

Pre- and post-hydration with normal saline has the most proven benefit in preventing contrast-induced nephrotoxicity.

What Is the Major Force Driving Filtration in the Kidney?

High hydrostatic pressure in the glomerular capillary is responsible for ensuring filtration in the nephron tubules. In situations where hydrostatic pressure in Bowman's space rises (postrenal AKI), filtering fluid becomes more difficult.

Watch Out

Increased BUN/creatinine ratio may be seen in conditions other than hypovolemia: upper gastrointestinal bleed (high protein absorption), increased urea production (steroid therapy), and/or low muscle mass (decreases serum creatinine creation).

Does Unilateral Ureteral Obstruction Lead to Renal Failure?

In most cases, this will not lead to renal failure unless the patient has a solitary kidney.

Is It Common to Have Oliguria Following Major Surgery? If so, Why?

Yes. This is a result of the response of the adrenal cortex and posterior pituitary to stress from surgery leading to fluid loss

and shifts. Aldosterone and antidiuretic hormone (ADH) released in the first 24 hours after surgery are primarily responsible for both salt and water retention (discussed in ► Sect. 40.5). Oliguria lasting longer than 24 hours warrants investigation.

Watch Out

Postoperative bleeding can present as oliguria. Lab values such as hemoglobin and hematocrit may be misleading in detecting acute hemorrhage in the postoperative setting. It generally takes 8–12 hours for interstitial fluid to redistribute into the vascular space, and blood concentration values will initially appear unchanged. In patients who receive fluid resuscitation, the hemoglobin will begin to drop over time as the fluid shifts into the plasma.

Can Prerenal AKI Lead to Intrarenal AKI and Eventually Renal Failure?

Prolonged periods of poor renal perfusion will directly damage the kidneys and lead to acute tubular necrosis (ATN), which will cause oliguria even after volume status and normal renal perfusion have been restored.

How Does General Anesthesia Affect Cardiac and Renal Function?

Most general anesthetics, commonly the inhaled volatile agents, result in myocardial depression and systemic vasodilation. This in turn can lead to a decrease in cardiac output and end-organ perfusion. In someone with no preexisting medical conditions or comorbidities, patients usually tolerate temporary fluctuations in their blood pressure without considerable change to their renal and cardiovascular function. However, patients with renal disease at baseline are more susceptible to insult resulting in worsening renal function.

Workup

What Is the Best Initial Test When Suspecting AKI?

The best initial tests are BUN and creatinine. A BUN/Cr ratio >20:1 with a clear history of hypoperfusion or hypotension is consistent with prerenal AKI.

What Other Tests Can Help Distinguish Between the Three Major Categories of AKI?

Urine sodium, fractional excretion of sodium (FE_{Na}) (► Table 40.2), and urine osmolality.

Table 40.2 FE_{Na} , U_{OSM} , U_{Cr}/P_{Cr} , and U_{Na}

	FE_{Na}	U_{OSM}	U_{Cr}/P_{Cr}	U_{Na}	BUN/Cr
Prerenal	<1%	>500	>40	<20	>20:1
Intrinsic renal	>1%	<350	<20	>40	<20:1
Postrenal	>4%	<50	<20	>40	<20:1

 FE_{Na} calculation

$$FE_{Na} = (U_{Na} / P_{Na}) / (U_{Cr} / P_{Cr})$$

U_{Na} urine sodium, P_{Na} plasma sodium, U_{Cr} urine creatinine, and P_{Cr} plasma creatinine

With prerenal AKI, decreased blood pressure and/or intravascular volume will increase aldosterone which subsequently increases sodium reabsorption in the kidneys and results in a decreased FE_{Na} . Additionally, low intravascular volume results in an increase in ADH released from the posterior pituitary. This will lead to increased water reabsorption from the urine, increasing urine osmolality and concentrating the urine to a dark yellow hue. The relevant laboratory values for AKI are presented in **Table 40.2**.

Watch Out

FE_{Na} is not reliable if the patient is receiving diuretics as they alter the renal excretion of sodium. In such a patient, the Fe_{Urea} may be helpful.

How Do Specific Gravity and the Presence of Cells/Casts in a Urinalysis Help?

Table 40.3

Finding	Suggests
High specific gravity	Volume depletion
Red cell casts	Glomerular disease
Hematuria	Renal emboli or stones
White blood cell casts	Infection or inflammation
Granular casts	Acute tubular necrosis

Watch Out

Urine dipstick is unable to differentiate between hemoglobin, myoglobin (rhabdomyolysis), and red blood cells.

Table 40.4 RIFLE criteria

Grade	Serum creatinine	GFR	Urine output
Risk	1.5-fold increase	Decrease by 25%	<0.5 ml/kg per hour for 6 hours
Injury	Twofold increase	Decrease by 50%	<0.5 ml/kg per hour for 12 hours
Failure	Threefold increase	Decrease by 75%	<0.3 ml/kg per hour for 24 hours or anuria for 12 hours
Loss	Complete loss of kidney function for more than 4 weeks		
ESRD	Complete loss of kidney function for more than 3 months		

ESRD end-stage renal disease

What Are the RIFLE Criteria?

This allows clinicians to grade levels of kidney dysfunction based on serum creatinine, glomerular filtration rate (GFR), and urine output (**Table 40.4**).

What Imaging Is Useful in the Workup of Oliguria?

Ultrasonography of the bladder, ureters, and kidneys is useful to assess for obstructive pathology. Bilateral or unilateral hydronephrosis with a BUN/Cr ratio less than 20:1 is highly suggestive of postrenal AKI. Doppler ultrasonography is a cost-effective means of evaluating renal perfusion.

Management

When Encountering Low Urine Output in a Patient With an Indwelling Foley Catheter, What Needs to Be Ruled Out First as an Easily Correctable Cause?

An obstructed urinary catheter needs to be ruled out first. One should first look for kinking in the tubing and flush the catheter to make sure it is not clogged.

What Should Be Done Next?

All medications should be reviewed, and all nephrotoxic drugs should be discontinued. In addition, all renally excreted drugs will need to be dose adjusted.

What Is a Fluid Challenge?

This involves giving an oliguric patient a bolus of normal saline (500–1000 ml) over a short amount of time (typically 30 min) in an effort to increase urine output. With a Foley catheter in place, urine output is recorded hourly. For patients with prerenal AKI due to hypovolemia with no other injuries to the kidney, urine output should increase. Raising the legs can simulate a fluid challenge (if the patient is hypotensive), but raising the legs is not therapeutic.

What if the Patient Does Not Respond to Repeat Fluid Challenges? How Do You Assess Adequacy of Fluid Replacement?

If repeat fluid challenges do not result in an improvement in urine output, the possibilities are either that the patient is still hypovolemic and needs additional fluid or the oliguria is not due to hypovolemia. The dilemma is whether to keep giving fluids and risk fluid overload. To help with this decision, a bedside ultrasound of the inferior vena cava (IVC) can be obtained, to assess the diameter and collapsibility (with inspiration) of the IVC, as these correlate with volume status. Alternatively, inserting a central venous catheter to measure the central venous pressure (CVP) may be performed. A normal CVP is 8–12 mmHg. Values below this indicates a persistently low intravascular volume and the need for additional fluid resuscitation. Once a normal CVP has been restored, if oliguria persists, postrenal and intrinsic renal etiologies must be considered.

Watch Out

Measuring CVP to determine volume status is infrequently done due to a series of studies that have questioned the accuracy of this technique. However, you need to know how to interpret the CVP.

What Should Be Done if the Patient Is Suspected of Having a Postrenal Obstruction?

Severe benign prostatic hypertrophy (BPH) or an obstructed urinary catheter can lead to postrenal obstruction. Insertion of a Foley catheter would be the first step in the management. If a Foley is already in place, replacing the catheter or irrigating it may be necessary.

What Are the Indications for Urgent/Emergent Dialysis?

If the patient remains anuric and the renal failure persists, hemodialysis may be performed. Indications for emergent

hemodialysis can be remembered with the AEIOU mnemonic: acidosis, electrolyte imbalance (hyperkalemia), intoxication (ethylene glycol), overload (fluid), and uremia (uremic encephalopathy, pericarditis, or platelet dysfunction).

What Is the Role of Diuretics in the Treatment of Oliguria?

Diuretics may be beneficial in the setting of cardiogenic oliguria (such as in association with decompensated congestive heart failure). Diuretics are otherwise not beneficial.

What Is the Theoretical Role of Dopamine in the Treatment of Oliguria? What Is the Actual Role?

Dopamine is an endogenous catecholamine which at low doses is known to increase the cardiac output while causing renal vascular dilation in an individual with normal renal function, thus theoretically improving perfusion to the organ and natriuresis while reducing the metabolic demands of the renal tubular system. However, dopamine can actually increase renovascular resistance in oliguric patients with AKI, further decreasing the blood flow to the kidney and worsening the insult. It has also been noted that dopamine can potentiate diuresis in patients who are already volume depleted, especially in patients who are receiving diuretics, as it augments the effects of diuretic agents. Dopamine is *not* currently recommended for the treatment of oliguria.

Area You Can Get in Trouble

MRI in Patient with Renal Failure

Patients with renal failure that undergo gadolinium-enhanced MRI are at risk for nephrogenic systemic fibrosis. Patients present with marked thickening and hardening of the skin in addition to fibrosis of internal structures, such as the muscle, fascia, lungs, and heart.

Summary of Essentials

History and Physical Exam

- AKI is often asymptomatic with only decreased urine output as the presenting sign
- Physical exam findings specific for AKI are rarely seen; the earliest sign is oliguria
 - Oliguria: <0.5 ml/kg/h for two consecutive hours
 - Anuria: <50 ml–100 ml/day

Physiology/Pathophysiology

- Three types of AKI:
 - Prerenal: BUN/Cr ratio >20:1 often with history of hypotension/hypovolemia
 - Intrinsic renal/intrarenal: sequelae of prerenal AKI, ATN, and interstitial nephritis
 - Postrenal: obstruction secondary to BPH, obstructed urinary catheter, tumor, stone, or stricture
- Contrast-induced AKI seen with preexisting renal disease
 - Increase in serum creatinine of 0.5 mg/dl within 48–72 hours
- Aldosterone and ADH primarily responsible for post-op oliguria

Workup

- The best initial tests are BUN and creatinine
- Urinalysis, urine sodium, fractional excretion of sodium (FE_{Na}), and urine osmolality

- RIFLE criteria to grade kidney dysfunction (serum creatinine, GFR, and urine output)
- Ultrasonography of the bladder, ureters, and kidneys is useful to assess for obstructive pathology

Management

- Flush Foley, discontinue nephrotoxic drugs, and perform fluid challenge
- Indications for urgent/emergent dialysis:
 - AEIOU: acidosis, electrolyte imbalance (hyperkalemia), intoxication (ethylene glycol), overload, and uremia

Suggested Reading

- Galan A, Cowper SE, Bucala R. Nephrogenic systemic fibrosis (nephrogenic fibrosing dermopathy). *Curr Opin Rheumatol*. 2006;18:614.
- Khawaja A. KDIGO clinical practice guideline for acute kidney injury. *Kidney Int Suppl*. 2012;2:8.
- Nash K, Hafeez A, Hou S. Hospital-acquired renal insufficiency. *Am J Kidney Dis*. 2002;39:930.



Shortness of Breath 5 Days After Surgery

Jacquelyn L. Phillips, Christian de Virgilio, Areg Grigorian, Paul N. Frank, and Jeffry Nahmias

Case Study

Five days after a laparoscopic left colectomy for colon cancer, a 55-year-old female presents to the emergency department with shortness of breath for the past 6 hours. She feels that she is breathing more rapidly and does not seem to be able to catch her breath. She denies any chest pain. Per report, the colon cancer was limited to the sigmoid colon, and the surgery was uneventful. She has no prior cardiac or pulmonary history. On physical exam, the

patient has a temperature of 37.9 °C, respiratory rate 26 cycles/min, heart rate 110 beats/min, and blood pressure 130/85 mmHg. Lungs are clear to auscultation without wheezing or rales. On cardiac exam, the patient has no murmurs or rubs. Her abdomen is soft and nontender. The wound appears to be clean without erythema or drainage. Her left leg appears to be swollen up to the knee with pitting edema. The left calf is not tender to

palpation. The right leg is not swollen. Distal pulses are normal. O₂ saturation on room air is 92%. Arterial blood gas on room air reveals a pO₂ of 70 mmHg, a pCO₂ of 33 mmHg, a pH of 7.47, and an A-a gradient of 25. Laboratory studies reveal a leukocytosis of 10,600/mm³, hemoglobin of 12 g/dL (12–15.2 g/dL), and hematocrit of 36% (37–46%). Chest x-ray is normal. Electrocardiogram (ECG) demonstrates sinus tachycardia but is otherwise unremarkable.

Diagnosis

What Is the Differential Diagnosis for Postoperative Shortness of Breath?

Table 41.1

Diagnosis	History and physical	Comments
<i>Pneumonia</i>	Fever, dyspnea, dullness to percussion, productive cough, prolonged intubation, aspiration, PPI use results in ↑gastric pH leading to ↑gram-negative bacteria growth in the stomach	Most common cause of nosocomial mortality, aspiration (right lower lobe if patient is upright, right upper lobe if patient is supine)
<i>Pulmonary embolism</i>	Recent travel (e.g., long airplane or car ride), immobilization, recent surgery, trauma or central line (within 3 months), cancer, history of DVT or PE, smoking, CVA, CHF, COPD, look for Virchow's triad (see below)	Usually from DVT in pelvic or leg veins
<i>Myocardial infarction</i>	H/o MI, diabetes, CHF, CAD	Surgery creates proinflammatory state, leads to plaque rupture and thrombosis of coronary artery
<i>Pneumothorax</i>	Diminished/absent breath sounds, associated with central line placement (US-guided line placement lowers risk)	Air leak in pleura allows equalization of negative pleural pressure with ambient pressure
<i>Cardiogenic pulmonary edema</i>	Rales, JVD, S3 gallop, bilateral leg swelling, orthopnea	PCWP >18 mmHg
<i>Noncardiogenic pulmonary edema</i>	Sepsis, massive transfusion, trauma, pancreatitis; no rales, S3, or JVD	PaO ₂ /FiO ₂ <200, hypoxemia with respiratory alkalosis; bilateral infiltrates on CXR, includes ARDS
<i>Anxiety</i>	Must rule out other causes first	Psychogenic
<i>Bleeding</i>	Hypotension, tachycardia, decreased urine output	Most often in the first hours after surgery

ARDS acute respiratory distress syndrome, CAD coronary artery disease, CHF congestive heart failure, COPD chronic obstructive pulmonary disease, CVA cerebral vascular accident (i.e., stroke), DVT deep vein thrombosis, JVD jugular venous distention, MI myocardial infarction, PCWP pulmonary capillary wedge pressure, PPI proton pump inhibitor

What Is the Most Likely Diagnosis?

The differential diagnosis for acute shortness of breath with hypoxia is extensive. The primary etiologies in the postoperative period are shown above. Pneumonia and cardiogenic pulmonary edema are high on the list; however, the absence of physical exam evidence of fluid overload (JVD, rales, or crackles) points against cardiogenic pulmonary edema. Similarly, a normal lung exam and normal CXR make pneumonia, atelectasis, and noncardiogenic pulmonary edema very unlikely. The combination of hypoxia, hypocapnea, respiratory alkalosis, tachycardia, and a wide A-a gradient points to a pulmonary embolus (PE). This is further reinforced by a normal CXR and ECG demonstrating only sinus tachycardia. Finally, the unilateral leg swelling suggests that the source of the PE is a lower extremity deep vein thrombosis (DVT). DVT and PE both comprise venous thromboembolism (VTE) disease.

History and Physical Exam

What Is Virchow's Triad? Which Part of the Triad Can Be Invoked in the Patient?

At least one of Virchow's triad is generally present when a VTE event occurs. The triad includes *stasis*, *endothelial injury*, and a *hypercoagulable state*. The patient described above has two of the triad: cancer, which is a cause of hypercoagulability, and stasis from being immobile during and after the operation. Surgery, just like other types of trauma, also induces a *hypercoagulable (prothrombotic) state*. Stasis occurs during prolonged bed rest such as after an injury, a surgery, or a long plane flight or car ride. Walking causes the leg muscles to act as a pump to move blood back to the heart. In the immobile patient, venous blood will tend to collect in the legs, leading to *stasis*. Hypercoagulable states can be congenital or acquired. Venous endothelial injury can occur after a trauma (leg fracture) or an iatrogenic event (venous cannulation with a central line).

What Are the Risk Factors for VTE and Their Mechanism?

Stasis

- Immobilization
- Surgery

Endothelial injury

- Trauma
- Central line within the last 3 months
- History of DVT or PE

Hypercoagulability

- Smoking
- Oral contraceptive pills
- History of DVT or PE
- Malignancy
- Inherited disorders (e.g., factor V Leiden, protein C deficiency)

What Is the Wells Score for PE?

The Wells score is calculated by adding the points associated with clinical findings in [Table 41.2](#). A score >4 points indicates a likelihood of PE, whereas a score ≤ 4 points indicates a low likelihood of PE.

What Are the Main Clinical Findings Associated with a DVT?

The main clinical findings are leg swelling, calf pain, warmth of leg, mild redness of calf, and calf tenderness to palpation.

Watch Out

The left leg is 2× more commonly affected by DVT because the left iliac vein may be compressed by the right iliac artery. This phenomenon is known as *May-Thurner syndrome*.

Table 41.2 Wells Score

Finding	Points
Signs and symptoms of DVT	3
PE most likely diagnosis	3
HR >100	1.5
Prior DVT or PE	1.5
Immobilization within the last 4 weeks	1.5
Malignancy within the last 6 months	1
Hemoptysis	1

What Is Homans' Sign? Why Has It Fallen Out of Favor?

Homans' sign is a physical exam finding that was classically associated with DVT. The sign is considered positive when you can elicit calf pain with dorsiflexion of the foot. It is no longer used routinely because it has a very low sensitivity of 30%, which limits its clinical utility.

What Are the Five Classic Causes (Five Ws) of Postoperative Fever and When in the Postoperative Setting Would Each Be Expected to Occur?

Table 41.3

W	Etiology	Post-op day
Wind	Atelectasis	1–2
Water	Urinary tract infection	After 3
Wound	Wound infection	After 5
Walking	DVT/thrombophlebitis	7–10
Wonder drugs	Drug fever (e.g., antibiotics)	Anytime

Watch Out

Another common cause of fever in surgical patients is a febrile nonhemolytic blood transfusion reaction. This can occur within the first 6 hours after transfusion. It is not uncommon to receive blood products during surgery, and so a fever in the immediate postoperative setting can be related to this.

respiratory alkalosis. The best way to prevent this complication is to encourage breathing exercises. An incentive spirometer is an excellent tool to help promote deep breathing after surgery. Recent studies have questioned whether atelectasis is actually a cause of postoperative fever.

What Are the Most Commonly Inherited Causes of Hypercoagulability (Thrombophilia)?

Factor V Leiden and prothrombin mutation are the first and second most common inherited thrombophilias. Less common inherited thrombophilias include protein C deficiency, protein S deficiency, antithrombin deficiency, and homocysteinemia.

Watch Out

Heparin-induced thrombocytopenia (HIT) may present as an acute drop in platelet levels (such that the new level is <50% of baseline) in a patient who has begun heparin or low molecular weight heparin (LMWH) therapy within the last 5–10 days. HIT is paradoxically a *hypercoagulable* state.

What Are the Most Common Acquired Causes of Hypercoagulability?

Advanced age, pregnancy, malignancy, oral contraceptives, hormone replacement therapy, obesity, nephrotic syndrome, and heparin-induced thrombocytopenia are common causes of acquired hypercoagulability. However, smoking is the most common acquired cause of hypercoagulability.

Watch Out

Factor V Leiden is the most common *inherited* cause of hypercoagulability and is associated with DVT. The most common *acquired* hypercoagulability is from smoking.

Pathophysiology

What Causes Atelectasis and How Is It Prevented?

Atelectasis is considered the most common postoperative pulmonary complication following surgery. It occurs because of airway obstruction from retained airway secretions, poor lung compliance, and difficulty with deep breathing due to pain or medication. In severe cases, the patient's arterial blood gas may demonstrate hypoxemia and

What if a Patient Has No Obvious Component of Virchow's Triad and Presents with Venous Thromboembolism (VTE)?

Always try to identify on history if the patient manifests any of the three parts of Virchow's triad. If there are no obvious risk factors (such as recent surgery, known malignancy,

recent trauma, plane flight, etc.), then a careful history and physical exam must be conducted to ascertain whether the patient has an undiagnosed malignancy or other hypercoagulable states.

What Is the Difference Between a Cardiac and Noncardiac Cause of Postoperative Pulmonary Edema?

Pulmonary edema is defined as excess fluid in the alveoli. There are both cardiac (i.e., cardiogenic) and noncardiac (i.e., noncardiogenic) etiologies. Noncardiogenic pulmonary edema is caused by inflammation that leads to an increased pulmonary capillary permeability secondary to cytokine signaling. Specific etiologies of noncardiogenic edema include pneumonia, ARDS, pulmonary contusion, and fat embolism. Cardiogenic pulmonary edema arises from an increase in hydrostatic pressure within the capillaries of the lungs as a result of increased pulmonary venous pressure.

How Do You Distinguish Between Cardiogenic and Noncardiogenic Pulmonary Edema Based on History and Physical Exam? Why Is It Important to Distinguish Between Them?

With cardiogenic pulmonary edema, there is usually an associated acute cardiac event, such as an MI, left ventricular failure, or dysrhythmia. Physical exam demonstrates evidence of acute heart failure and a low flow state, such as S3 gallop, jugular venous distention, and crackles on auscultation, as well as cool, pale extremities (these findings are not present with noncardiogenic causes). Cardiogenic pulmonary edema is definitively demonstrated by measuring an elevated (>18 mmHg) pulmonary capillary wedge pressure (PCWP), whereas PCWP is normal or low with noncardiogenic causes. Treatments of cardiogenic causes include reduction of preload, reduction of afterload, and, if needed, the addition of pressors (such as dobutamine). The mainstay of treatment for noncardiogenic pulmonary edema is ventilatory support.

Watch Out

Cardiogenic pulmonary edema on post-op day 3 may be the result of third spacing. The large volume of IV fluids administered to the patient perioperatively, which

equilibrated in all body compartments, will return back to the vasculature often on post-op day 3. Elderly patients or those with poor heart function are particularly at risk, as the increased intravascular volume may overwhelm the heart and lead to elevated ventricular filling pressures, which can be transmitted into the pulmonary circulation.

What Are the Three Routes by Which a Patient Develops Postoperative Pneumonia?

Postoperative pneumonia may be acquired via inhalation, aspiration, or hematogenous spread. After surgery, the cough reflex may be suppressed, and mucociliary transport may be inhibited by endotracheal intubation. Additionally, alveolar macrophage function may be inhibited by pulmonary edema. Accumulation of oral secretions in the airway is also a risk factor.

What Is an A-a Gradient? What Is the Differential of a Wide A-a Gradient?

A-a gradient refers to the difference in partial pressure of oxygen between the alveolar ($P_{A_{O_2}}$) and arterial blood ($P_{a_{O_2}}$). The differential diagnosis of a wide A-a gradient in the postoperative setting includes atelectasis, pneumonia, and pulmonary embolism.

The normal A-a gradient, $P_{A_{O_2}} - P_{a_{O_2}}$, is given by

$$\text{normal A-a gradient} = \frac{\text{age in years}}{4} + 4$$

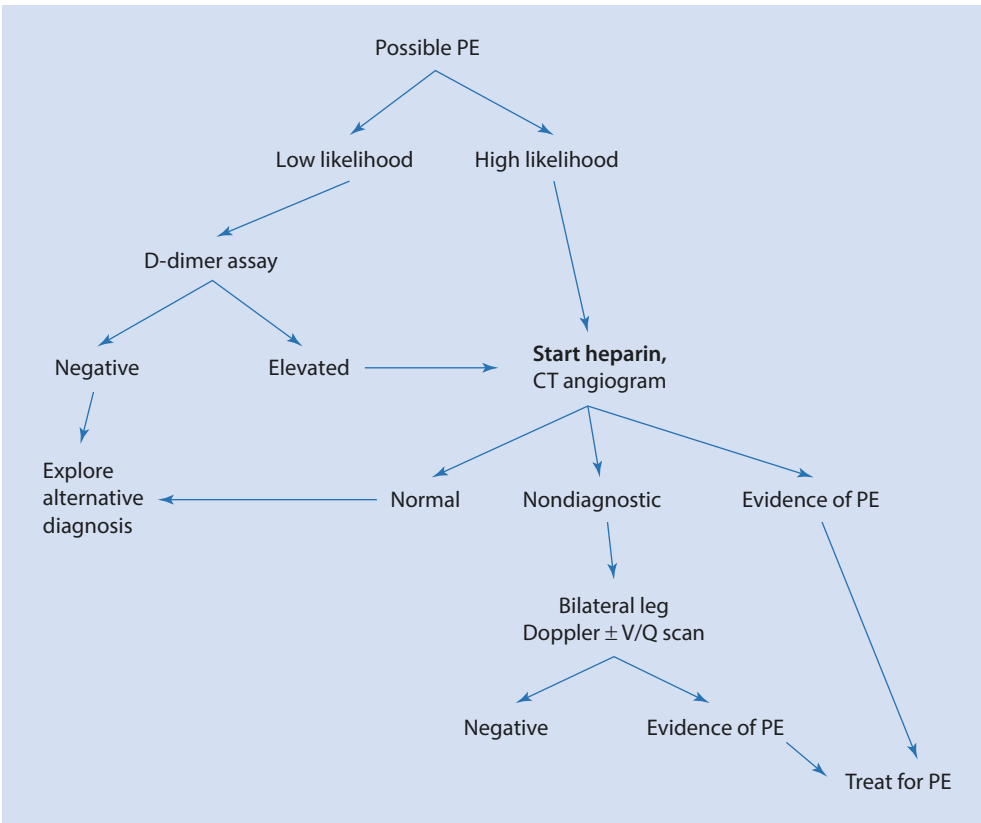
Workup

What Is the First Step in the Workup of a Patient Suspected of Having a Pulmonary Embolism?

Determine the likelihood that the patient has a pulmonary embolism using the Wells score. If their score is ≤ 4 , the patient has a low likelihood of PE. If the score is >4 , the patient has a high likelihood of PE. This will then determine the next step in the workup.

What Is the Full Diagnostic Algorithm for a Possible Pulmonary Embolism? (Fig. 41.1)

Fig. 41.1 Low likelihood is based on Wells score ≤ 4 . D-dimer assay is considered normal if the D-dimer level is <500 ng/dL



When There Is a High Suspicion of VTE, What Is the First Step in the Workup/Management?

Start therapeutic heparin right away *before* the diagnosis is even established. Heparin is an anticoagulant—not a fibrinolytic. Hence, the purpose of heparin in VTE is not to dissolve the clot, but rather to prevent it from progressing/propagating. Following heparin administration, one should obtain a CT angiogram of the pulmonary arteries.

When Suspicion of VTE Is Low, What Is the First Step in the Workup?

The first step is to obtain a D-dimer assay. D dimer is a product of the breakdown of fibrin by plasmin. There are many causes of elevated D-dimer levels, including VTE, recent surgery, malignancy, DIC, infection, pregnancy, and renal and cardiovascular disease. Hence, D dimer has very low specificity, particularly in the postoperative setting. That being

said, D dimer has a high negative predictive value. So, even though most postoperative patients will have an elevated D dimer, a D-dimer level <500 ng/mL effectively can rule out PE in low-risk patients. If D dimer is elevated, the next step is to obtain a CT angiogram.

In a Patient with PE, What Are the Most Common Findings on ABG, ECG, and CXR?

Table 41.4

Study	Most common finding
Arterial blood gas (ABG)	Acute respiratory alkalosis, hypoxemia, hypocapnea, increased A-a gradient
Electrocardiogram (ECG)	Sinus tachycardia
Chest x-ray (CXR)	Normal

What Are the Classic, Though Uncommon, Findings on CXR and ECG That Are Associated with PE?

Westermarck's sign (focal/regional pulmonary oligemia distal to embolus) on CXR represents a region of decreased pulmonary blood flow secondary to PE. It is highly specific but has a very low sensitivity. Hampton's hump (wedge-shaped density at periphery of the lung) is another uncommon sign suggesting PE. The classic constellation of ECG findings is large S wave in lead I, large Q wave in lead III, and inverted T wave in lead III. This is seen in only 20% of patients and is a sign of right ventricular strain.

Since CXR and ECG Are Often Normal with a PE, How Do They Help?

CXR is actually quite useful in the diagnosis of PE, in that a normal CXR (no infiltrates, atelectasis, or fluid overload) in a hypoxic patient strengthens the suspicion for PE. Likewise, a normal ECG (other than sinus tachycardia) helps to rule out cardiac causes (MI, arrhythmia) of shortness of breath.

What Are the Typical Findings on CT Angiography for PE? What Is the Sensitivity and Specificity?

CT angiography in PE (■ Fig. 41.2) will show a filling defect in the pulmonary arterial system. The sensitivity may range from 91% to 100%, and the specificity ranges from 83% to 93%.



■ Fig. 41.2 Axial CT angiogram showing a filling defect in the left pulmonary artery consistent with pulmonary embolism

Watch Out

A large saddle embolus lodged in the common pulmonary artery can result in sudden death secondary to right heart failure.

How Does V/Q (Ventilation/Perfusion) Scan Work? Why Has It Fallen Out of Favor for the Diagnosis of PE?

Inhaled and intravenous radionuclides are administered, and their distribution throughout the lung fields is imaged. High suspicion for a PE occurs when there are multiple areas of perfusion deficit with normal lung ventilation. The results of a V/Q scan are given as high, intermediate, low, and very low probability of PE. The V/Q scan has fallen out of favor in the diagnosis of PE because of the time it takes to perform, lack of availability at nights and weekends, and questions about its predictive value, as a significant percentage of patients with low probability of PE on V/Q scan will end up actually having a PE.

If the Patient Is Critically Ill and Unable to Be Transported for Imaging, What Bedside Options Are There for the Indirect Diagnosis of PE?

Echocardiogram may show indirect evidence of PE, such as right heart strain (if the PE is large). Since most PE arise from DVT in the legs, a venous duplex (*Doppler ultrasound*) of the legs may demonstrate a venous thrombus.

How Is the Severity of PE Classified?

PE is classified into low-risk, submassive, and massive PE. The classification is important as it affects management and prognosis. A low-risk PE has no evidence of right ventricular (RV) dysfunction and no evidence of myocardial necrosis. A submassive PE has been defined as evidence of RV dysfunction on echocardiogram or myocardial necrosis (based on elevated troponin or brain natriuretic peptide {BNP}) in the absence of systemic hypotension (systolic BP ≥ 90 mmHg). With a massive PE, there is the addition of sustained hypotension.

Watch Out

Patients with an IVC filter have a higher risk of developing a DVT but lower risk of developing a PE.

Management

What Is the Initial Anticoagulant Management of PE?

The initial management of PE is therapeutic anticoagulation with subcutaneous low molecular weight heparin (LMWH) or intravenous unfractionated heparin. LMWH should be *avoided* in patients with renal dysfunction. In patients with a suspected high probability of PE, anticoagulation should be instituted immediately while the diagnostic workup is in progress, provided there are no contraindications to anticoagulation.

What if the Patient Has a History of or Suspected Heparin-Induced Thrombocytopenia (HIT)?

A non-heparin-based anticoagulant should be given such as argatroban or bivalirudin. These are direct thrombin inhibitors.

What Are the Four Options for the Subsequent Treatment of PE?

Once the diagnosis of PE is established, depending on the severity of the PE, patients may receive heparin alone, tPA (a thrombolytic agent), endovascular clot aspiration, or open pulmonary embolectomy. In most patients (low-risk PE), heparin alone is sufficient.

When Should tPA Be Considered?

Intravenous tPA is *indicated* in patients with massive PE, *should be considered* in select patients with submassive PE, and is *not indicated* in low-risk PE. Contraindications to tPA include surgery within the last 2 weeks (such as in the patient described above), intracranial hemorrhage or malignancy, ischemic stroke within the last 3 months, suspected aortic dissection, active bleeding (other than menses), significant closed head trauma within 3 months, and severe hypertension (>185/110 mmHg). The greatest risk of tPA is fatal hemorrhage, including intracranial.

When Should Open Pulmonary Embolectomy Be Considered?

Open pulmonary embolectomy may be considered in patients with massive PE who are not candidates for tPA therapy.

What if the Patient Has a Contraindication to Anticoagulation?

If the patient has a contraindication to anticoagulation, such as ongoing bleeding or recent intracranial hemorrhage, this is an indication for placement of an inferior vena cava filter (once the presence of PE has been confirmed).

What Is the Recommendation for Long-Term Anticoagulation After First-Time VTE?

Heparin or LMWH should be given for the first 5 days after VTE, and warfarin should be started on the first or second day such that the two anticoagulants overlap for 4–5 days. The goal INR should be 2–3. Patients should receive anticoagulation therapy for at least 3 months after VTE (when there is a reversible risk, such as in the recent surgery). For recurrent or unprovoked VTE, treatment is for at least 6 months. More recently new oral anticoagulants (NOACs) such as dabigatran, rivaroxaban, and apixaban have become a reasonable alternative to warfarin in select cases, with the advantage of not requiring frequent blood draws for monitoring.

Watch Out

Rivaroxaban is renally cleared so should be avoided in patients with renal dysfunction.

Areas Where You Can Get in Trouble

Anticoagulation in Patients with Malignancy

Warfarin is the most frequently used long-term anticoagulant, but LMWH is better than warfarin in preventing recurrent VTE in patients with malignancy and therefore is the anticoagulant of choice in the setting of malignancy.

Anticoagulation During Pregnancy?

PE is a significant cause of maternal death in the United States, so aggressive therapy is warranted. Anticoagulation with LMWH or unfractionated heparin should be used to treat VTE in pregnancy. Warfarin is a teratogen and should not be given to pregnant women.

PE Can Mimic Sepsis

PE can mimic sepsis as the patient may present with fever, tachycardia, hypotension, and leukocytosis.

Summary of Essentials

History and Physical Exam

- Look for Virchow's triad (stasis, hypercoagulability, and endothelial injury).
- Check for sudden onset of dyspnea, pleuritic chest pain, and/or tachycardia.
- Calculate Wells score.

Pathophysiology

- DVT is most likely to form in the leg or pelvic veins, also at the site of intravenous catheter insertion, and less commonly in the arms.

Differential Diagnosis

- Patients with shortness of breath and pleuritic chest pain should also be evaluated for pulmonary edema (cardiogenic and noncardiogenic), myocardial infarction, and pneumonia.

Diagnosis

- If there is high suspicion of PE, start heparin immediately, even before the workup is completed.
- Patients with high suspicion of PE should undergo CT angiography.
- If CT angiogram is nondiagnostic, patients should undergo V/Q scanning.
- D-dimer, BNP, and troponin labs should be sent.

- Echocardiogram may be used to assess for evidence of right heart strain (particularly if BP low or troponin elevated).
- ECG will most commonly show sinus tachycardia in patients with PE.

Management

- IV heparin or subcutaneous LMWH
- Submassive PE—IV heparin or subcutaneous LMWH + consider tPA
- Massive PE—tPA vs. pulmonary embolectomy
- IVC filter—only if contraindication to anticoagulation

Special Conditions

- VTE with malignancy—LMWH: treatment of choice
- VTE in pregnancy—avoid warfarin
- VTE with HIT—direct thrombin inhibitors (e.g., argatroban)

Suggested Reading

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Question Set: Surgical Complications

Questions

1. A 78-year-old male is in the recovery room after an open inguinal hernia repair. His blood pressure is noted to be 70/55 mmHg, and pulse is 118/min. He is breathing normally. The patient has a history of hypertension for which he takes a diuretic. The operation itself was uneventful except that the nurses had difficulty inserting the urinary catheter. Given the hypotension, the patient is transferred to the ICU for close monitoring. The following hemodynamic parameters are obtained: cardiac output of 10.2 L/min (normal 5 L/min) and systemic vascular resistance of 450 dynes/sec/cm-5 (normal 700–1600 dynes/sec/cm-5). What is the next step in treatment?
- (A) Phenylephrine
 - (B) Dopamine
 - (C) Blood cultures and broad-spectrum antibiotics
 - (D) IV bolus of lactated Ringer's
 - (E) Norepinephrine
2. A 25-year-old woman is referred to an ENT surgeon with complaints of recurrent nosebleeds for the past month. She also reports that she has been easily bruising with minor trauma and her last menstrual period required double the change of tampons she typically uses. She does not report any blood in the stool or urine. Her physical exam is significant for mild gingival bleeding and scattered bruises on her arms and legs. Her laboratory exam is significant for an isolated thrombocytopenia of 13,000 cells/ml (normal 150,000–400,000 cells/ml). Bone marrow biopsy is normal other than an increase in megakaryocytes. What is the best initial management for this condition?
- (A) Platelet transfusion
 - (B) Corticosteroids
 - (C) Splenectomy
 - (D) Plasmapheresis
 - (E) Intravenous immunoglobulin (IVIG)
3. A 60-year-old female returns to the emergency department for right leg swelling 1 week after undergoing a right hemicolectomy for cecal adenocarcinoma. Duplex scan confirms a deep vein thrombosis and the patient is started on IV heparin. The patient's hospital course is further complicated by a urinary tract infection and pneumonia. On hospital day 7, the morning laboratory study shows a platelet count of 55,000 cells/ml, down from a baseline of 140,000 cells/ml. What is the next immediate step?
- (A) Stop heparin.
 - (B) Stop heparin and start a direct thrombin inhibitor.
 - (C) Stop heparin and switch to low molecular weight heparin (LMWH).
 - (D) Transfuse two units of platelets.
 - (E) Start corticosteroids.
4. A 68-year-old female presents to the emergency department three days after total hip replacement. She became suddenly short of breath 2 hours ago. Her vitals include a blood pressure of 100/60 mmHg, heart rate of 120 beats/min, and respiratory rate of 30 cycles/min. On physical examination, lung sounds are clear. Chest x-ray is normal.

Arterial blood gas shows a pH of 7.53, PaCO₂ 28, PaO₂ 70, and HCO₃ 25. Oxygen is given by nasal cannula. Which of the following is the next best step in the management?

- (A) Spiral CT angiogram of the chest
- (B) Intravenous heparin
- (C) Intravenous thrombolytic infusion
- (D) Venous duplex scan of both legs
- (E) Echocardiogram

5. A 45-year-old patient undergoes an open hernia repair. He is a smoker. On postoperative day 2, his wound appears to be healing well, and he is discharged home. What type of operative wound is this considered to be?

- (A) Clean
- (B) Clean contaminated
- (C) Contaminated
- (D) Dirty infected
- (E) Elective

6. A 29-year-old female who is 8 months pregnant presents with symptoms and signs of acute cholecystitis and undergoes laparoscopic cholecystectomy uneventfully. However, she returns to the emergency department on postoperative day 4 with acute-onset dyspnea and pleuritic chest pain. A pulmonary embolism is subsequently diagnosed. What is the most likely source of the thromboembolism?

- (A) The right common iliac vein
- (B) The left common iliac vein
- (C) The right popliteal vein
- (D) The right axillary vein
- (E) The left femoral vein

7. A 50-year-old female undergoes right hepatic lobectomy for metastatic colon cancer. The operation took 6 h and was associated with significant bleeding. As a result, she was markedly hypotensive throughout the operation and received multiple units of blood products. She was admitted to the surgical ICU for further management. She received one dose of prophylactic antibiotics preoperatively but is otherwise not receiving any medications. On postoperative day 1, her urine output is only 10 cc/h for 5 h. Her serum creatinine has risen from 1.2 to 2.0 mg/dl. Her blood pressure is 140/80 mmHg, and heart rate is 100 beats/min. Lungs are clear to auscultation. Urine Na is 44 mEq/L, and FE-Na is 3.1%. Which of the following is the most likely etiology?

- (A) Hypovolemia
- (B) Acute interstitial nephritis
- (C) Acute tubular necrosis
- (D) Cardiogenic shock
- (E) Obstructed urinary catheter

8. A 64-year-old female was recently discharged following morbid obesity surgery (gastric sleeve resection). Her postoperative course was complicated by a deep vein thrombosis (DVT) in her left leg, for which she received intravenous heparin and discharged with oral warfarin. She now presents with an area of discolored, purplish skin on her right thigh that began the prior day and is extremely painful. On physical exam, she is afebrile with a normal blood pressure and heart rate. There is a 6 × 6 cm area of purplish-black skin over her right anterior thigh and another smaller area on her right calf. On laboratory exam, her white blood cell count and serum glucose are normal. What is the most likely cause?

- (A) Vitamin K deficiency
- (B) Protein C deficiency
- (C) Heparin
- (D) Thrombocytopenia
- (E) Unrecognized hemophilia

9. A 40-year-old male is hospitalized after a hip replacement. On postoperative day 3, the astute medical student notices he has a new left-sided facial droop. Cardiac examination demonstrates a regular rate and rhythm without murmurs. Further exam reveals left arm and leg weakness and numbness. In addition, he has a swollen right calf that is 3 cm larger in diameter than the left calf when measured 10 cm below the tibial tubercle. Venous duplex ultrasound shows a noncompressible right femoral vein. What test is most likely to explain the etiology of the neurologic findings?
- (A) Electrocardiogram (ECG)
 - (B) CT of the chest
 - (C) Factor V Leiden testing
 - (D) Echocardiogram with bubble study
 - (E) Duplex ultrasound of the carotid artery
10. Which of the following findings on urinalysis would most strongly support the diagnosis of acute tubular necrosis (ATN)?
- (A) Muddy brown casts
 - (B) Urine osmolality >500
 - (C) Bland urine sediment
 - (D) Red cell casts
 - (E) White cell casts
11. A 65-year-old homeless man with poorly controlled diabetes presents to urgent care with severe pain and swelling in his left leg. Vital signs include a temperature of 38.8 °C, blood pressure of 132/78 mmHg, and heart rate of 102 beats/min. On physical exam, he appears to be tachypneic. His left leg appears tense, and the skin is warm and red over his thigh and is tender to palpation. There is an area of the skin on the thigh that has a violaceous color with blistering. Laboratory testing demonstrates a white blood cell count of $22 \times 10^3/\mu\text{L}$ (normal $4.1\text{--}10.9 \times 10^3/\mu\text{L}$) with neutrophilic predominance and a serum Na of 128 mEq/L (137–145 mEq/L). What is the best next step in treatment?
- (A) Immediate IV heparin
 - (B) Venous duplex scan of the left leg
 - (C) CT pulmonary angiogram
 - (D) Blood cultures, broad-spectrum antibiotics, and urgent surgical debridement
 - (E) Blood cultures and broad-spectrum antibiotics
12. A 55-year-old woman with end-stage renal disease arrives to the emergency department with a 3-h history of severe epigastric pain that has been progressing in severity. She describes it as sharp, diffuse, and constant. Her past medical history is significant for chronic atrial fibrillation for which she takes warfarin. Her temperature is 37.8 °C, blood pressure is 102/66 mmHg, and pulse is 98/min and irregular. Physical examination reveals a diffusely tender and rigid abdomen, with guarding and rebound. An upright abdominal x-ray demonstrates free air under the right hemidiaphragm. Her laboratory exam findings include a hemoglobin 10.2 g/dl (normal 12–15 g/dl), platelets 110,000 cells/ml (150,000–400,000 cells/ml), INR 2.5, and PTT 18 s (18–28 s). Which of the following is the best way to manage the INR in this patient?
- (A) Hold warfarin and allow INR to autocorrect.
 - (B) Fresh frozen plasma.
 - (C) Prothrombin complex concentrate.
 - (D) Intravenous vitamin K.
 - (E) Cryoprecipitate.
13. What is the most common chest x-ray finding in a patient with pulmonary embolism (PE)?
- (A) Consolidation of one lobe
 - (B) Fluffy bilateral infiltrates
 - (C) Normal
 - (D) Hampton's hump (a wedge-shaped, pleural-based consolidation)
 - (E) Westermark's sign (a focus of oligemia leading to collapse of pulmonary vessel)

14. What is the most common electrocardiogram (ECG) finding in a patient with PE?
- (A) Right ventricular strain
 - (B) Right-axis deviation
 - (C) S1Q3T3
 - (D) Sinus tachycardia
 - (E) Right bundle branch block
15. What is the most common initial acid/base abnormality seen in patient with a pulmonary embolus (PE)?
- (A) Respiratory alkalosis
 - (B) Respiratory acidosis
 - (C) Metabolic alkalosis
 - (D) Metabolic acidosis
 - (E) Combined respiratory alkalosis and metabolic acidosis
16. A 61-year-old obese female with a past medical history of diabetes undergoes laparoscopic cholecystectomy for acute cholecystitis. The operation is technically difficult and is converted to an open cholecystectomy. Twelve hours later, the patient complains of severe pain in the wound. She has a temperature of 38.9 °C, heart rate of 120 beats/min, and a blood pressure of 110/70 mmHg. She appears ill. There is grayish foul-smelling drainage coming from the wound, which appears erythematous, swollen, indurated, and tender to touch. What is the next step in the management?
- (A) Reassure patient that wound infections do not occur so soon after surgery.
 - (B) Open a few of the wound staples to allow drainage.
 - (C) Broad-spectrum antibiotics.
 - (D) Return to the operating room for reclosure of the fascia.
 - (E) Broad-spectrum antibiotics and return to the operating room for aggressive wound debridement.
17. A 51-year-old male is brought to the emergency department by paramedics following a high-speed motor vehicle accident. His blood pressure is 120/70 mmHg, and heart rate is 100 beats/min. Hemoglobin and hematocrit are 12 g/dL (13.2–16.2 g/dL) and 36% (40–52%), respectively. A CT scan shows a ruptured spleen, and he is taken urgently to the operating room. During surgery, the patient is hemodynamically stable and undergoes a splenectomy. No other injuries are found, and he does not require blood transfusion. Four hours postoperatively, the patient's blood pressure drops to 80/50 mmHg, heart rate is 120 beats/min, and urine output, which was 50 cc/h for the first 2 h after surgery, is 10 cc/h for the past 2 h. The patient is awake and only complains of thirst. He appears pale. Breath sounds are clear. Despite 2 liters of IV fluids, the blood pressure remains 80/50 mmHg. Repeat hemoglobin and hematocrit are 10 g/dL and 30%. What is the next step in the management?
- (A) CT scan
 - (B) Diagnostic peritoneal lavage (DPL)
 - (C) 12-lead electrocardiogram (ECG)
 - (D) Chest x-ray
 - (E) Return to the operating room

Answers

- ✓ 1. Answer D
- The patient is in shock. Given the high cardiac output, and low systemic vascular resistance, septic and anaphylactic shock are the most likely. However, since the patient has not had any medications or unusual exposures and is breathing normally, it is most likely septic shock. Patients with difficult urinary catheterizations may have subsequent bacteremia which can result in septic shock. The first step in management of septic shock is aggressive IV fluid resuscitation with either normal saline (NS) or lactated Ring-

er's (LR). Norepinephrine (E) is considered as the first-line vasopressor for septic shock (E). Additionally, vasopressin can be used in combination with norepinephrine. Epinephrine is also used for septic shock, but after the above two. Dopamine was initially believed to increase renal perfusion in patients with shock, but studies have failed to consistently demonstrate this (B). It is not typically recommended for patients with septic shock (except for the rare patient with associated bradycardia). Phenylephrine is not recommended for septic shock except in highly selected patients (A). All patients with septic shock should also receive blood cultures, ideally before starting broad-spectrum antibiotics (but this should not delay initiation of antibiotics) (C).

- ✓ 2. Answer B
In a young patient presenting with recurrent epistaxis, isolated thrombocytopenia, and bleeding symptoms, an isolated acquired thrombocytopenia should be considered. Immune thrombocytopenic purpura (ITP) is an autoimmune disease characterized by autoantibodies against platelets and thus is considered a consumptive process. In a patient with a platelet count $<30,000$ and bleeding symptoms, the recommended initial management is corticosteroids (B). If this does not control the symptoms, the next line of therapy includes IVIG, dapsone, or danazol (E). Splenectomy is considered a last resort after medical therapy fails (C). Platelet transfusion should not be administered to a patient with ITP because it is considered a consumptive process (A). Plasmapheresis is not one of the recommended treatments for ITP (D).
- ✓ 3. Answer B
The findings here are consistent with heparin-induced thrombocytopenia (HIT), an immune reaction to heparin and platelet-factor-4 complexes. Despite the decrease in platelet count, this is a hypercoagulable state. Heparin should be discontinued immediately, and the patient should be started on a direct thrombin inhibitor (e.g., argatroban). LMWH also has a risk of HIT (C). Platelet transfusion is not indicated with a platelet count of 55,000 cells/ml (D). Corticosteroids would not be appropriate for the management of HIT (E).
- ✓ 4. Answer B
The patient presented has a high likelihood of pulmonary embolus (PE), based on Wells criteria. The patient is in the postoperative setting, the chest x-ray is normal, and the patient is tachycardic and slightly hypotensive, suggesting possible right heart strain from a massive PE. As such, the first step is to immediately start IV heparin, even before the diagnosis is confirmed with spiral CT angiogram of the chest (A). In patients with a low likelihood of PE, a D-dimer assay should be ordered first. Since D-dimer levels are often elevated after surgery, it has very poor specificity in the postoperative setting. That being said, D-dimer has a high negative predictive value. So even though most postoperative patients will have an elevated D dimer, D-dimer level <500 ng/mL effectively can rule out PE in low-risk patients. IV thrombolytic infusion would not be an appropriate management because the patient just had a major surgery (C). Venous duplex scan of both legs could subsequently be done to evaluate for deep vein thrombosis as the source for PE (D). Echocardiogram can be considered if CT angiogram is unrevealing (E).
- ✓ 5. Answer A
There are four types of operative wounds. These are used to predict the likelihood of a postoperative wound infection and to guide the use of preoperative antibiotics. Clean wounds (class-I) are those that do not involve entering an organ or cavity that is known to harbor bacteria (such as the alimentary, genitourinary, or reproductive tracts). Examples would be skin, eye, brain, and elective orthopedic surgery or hernia repair. Clean-contaminated (class-II) wounds are those in which an aseptically made wound enters the alimentary, respiratory, or genitourinary tracts (e.g., elective bowel resection, caesarean section) (B). Contaminated (class-III) wounds occur secondary to trauma, breaks in sterile technique, or gross spillage from the gastrointestinal tract

(e.g., penetrating wound to the bowel) (C). Dirty-infected (class-IV) wounds are those involving a preoperative infection (drainage of an abscess) or perforated viscera (e.g., abscess) (D). Elective wound is not a recognized type of wound (E). Patients that have optimized oxygen delivery to tissue are most likely to have normal wound healing. Factors known to increase the risk of wound infections include wound ischemia, diabetes, low albumin, steroids, poor arterial flow (e.g., peripheral arterial disease), smoking, and hypothermia.

✓ 6. Answer B

Deep vein thrombosis (DVT) occurs more commonly in the left leg than the right due to the fact that the right common iliac artery often compresses the left common iliac vein (this condition is termed May-Thurner syndrome). The risk of DVT is further increased in pregnancy due to the gravid uterus causing further compression. The other sites listed are less common locations of DVT (A, C–E). Note that pregnant women cannot be treated with warfarin due to its teratogenicity.

✓ 7. Answer C

The patient is oliguric and has evidence of acute kidney injury (AKI). The high urine Na (>40 mEq/L) and FENa $>1\%$ indicate an intrinsic (renal) etiology of AKI. The most common cause of renal AKI is acute tubular necrosis (ATN). Prolonged periods of poor renal perfusion directly damage the kidneys and lead to ATN. Hypovolemia causes prerenal azotemia (A). Acute interstitial nephritis also causes intrarenal AKI (B). However, it is less common than ATN and is an immune-mediated response to certain medications (e.g., penicillin, cephalosporins, sulfa drugs, NSAIDs). Classic findings include fever, rash, arthralgia, and urinary eosinophilia. Cardiogenic shock can lead to prerenal AKI due to decreased renal perfusion (D). Prolonged urinary obstruction due to bilateral ureteral obstruction can lead to postrenal AKI. Urine findings are variable. An obstructed Foley catheter is a potential cause of oliguria but is unlikely to cause AKI and certainly not so soon after surgery (E).

✓ 8. Answer B

The history and exam are most consistent with warfarin-induced skin necrosis. Warfarin inhibits the carboxylation of the vitamin K-dependent clotting factors: II, VII, IX, X, protein C, and protein S. This can acutely lead to the relative deficiency of protein C, owing to its short half-life, and thus can result in an initial hypercoagulable state and subsequent thrombosis in the vasculature supplying the skin. Warfarin-induced skin necrosis is more common in patients who have a preexisting protein C deficiency. Vitamin K deficiency is seen with severe nutritional depletion and intestinal malabsorption and manifests with bruising and hemorrhage (A). Heparin can cause skin necrosis as well, but this is seen locally at the site of injection (patient however received IV heparin) and in a much smaller distribution (C). Thrombocytopenia results in petechiae, not skin necrosis (D). Patients with hemophilia may have a history of deep tissue bleeding into muscles and joints (hemarthrosis) and oftentimes have excessive bleeding after surgical procedures, but not skin necrosis (E).

✓ 9. Answer D

The patient has symptoms and signs of a postoperative stroke. Most postoperative strokes are ischemic in nature (not hemorrhagic), and most ischemic strokes are embolic, arising from either the heart (in the setting of atrial fibrillation) or from a plaque at the carotid bifurcation in the neck. This patient, however, has a deep vein thrombosis (DVT). The combination of an acute DVT and a stroke suggests a paradoxical embolism, wherein a clot from the venous system enters the systemic (as opposed to pulmonary) circulation. The most likely explanation is an intracardiac shunt such as patent foramen ovale (PFO) or atrial septal defect (ASD). Such an anomaly would best be demonstrated with an echocardiogram with a bubble study. ECG might be helpful if atrial fibrillation was suspected; however, the patient has a regular rate and rhythm (A). In the setting described above, a CT of the head would be the first study indicated.

Head CT would confirm whether the patient did have a stroke and whether the stroke was ischemic or hemorrhagic (but this was not an option). CT of the chest would be helpful if PE were suspected (B). Factor V Leiden testing is not routinely recommended following a first-time DVT (C). Duplex ultrasound of the carotid arteries may identify a plaque, but the patient above is very young to have a carotid stenosis, and the concomitant DVT should raise a higher suspicion for paradoxical embolism (E).

✓ 10. Answer A

In ATN, the renal tubular epithelial cells die and slough off into the urine. These appear as muddy brown casts. Urine osmolality >500 and bland urine sediment are both consistent with a prerenal AKI state (B–C). Red cell casts are suggestive of injury to the glomerulus (e.g., glomerulonephritis) (D). White cell casts are suggestive of tubulointerstitial disease or acute pyelonephritis but may also be observed with many glomerular disorders (E).

✓ 11. Answer D

The patient is homeless which predisposes him to unsanitary conditions. Poorly controlled diabetes itself is an immunosuppressed state. Given this information about the patient, the presence of marked leukocytosis and hyponatremia, and his physical exam findings (e.g., painful, erythematous, swollen leg with bullae and violaceous skin), this patient likely has necrotizing fasciitis. Management consists of blood cultures, broad-spectrum antibiotics, and urgent surgical debridement. Antibiotics and cultures alone would not be appropriate (E). Choices A–C are all appropriate considerations for patients presenting with a PE secondary to DVT.

✓ 12. Answer C

The ideal method for reversing an elevated INR in a patient receiving warfarin depends on the urgency with which reversal is needed. The patient presented has peritonitis and free air under the diaphragm. As such, urgent surgery is required, and therefore urgent reversal of INR is necessitated. Of the choices provided, prothrombin complex concentrate (PCC) would provide the most immediate reversal (within 30–45 min). In addition, the smaller volume of PCC required to reverse INR will help avoid fluid overload in this patient with end-stage renal disease. Fresh frozen plasma can also help reverse INR but will work slower than PCC (B). Holding warfarin is not acceptable as it would take 3–4 days for reversal (A). Oral vitamin K takes about 24 h, whereas IV vitamin K takes about 8–12 h (D). Such strategies would be acceptable if surgery was not urgent. Cryoprecipitate has high levels of fibrinogen and von Willebrand factor but is not effective for warfarin reversal (E).

✓ 13. Answer C

Virchow's triad (hypercoagulability, immobility, endothelial injury) is a common risk factor for PE. Patients can present with dyspnea, pleuritic chest pain, cough, tachycardia, and/or hemodynamic instability. Most will have a normal-appearing chest x-ray. If present, the most common abnormality is a platelike atelectasis with decreased lung volume. Hampton's hump is seen in 20% of patients with PE and is characterized by a wedge-shaped, pleural-based consolidation frequently seen laterally (D). Westermarck's sign (focal/regional pulmonary oligemia distal to embolus) is even more rare and only seen in cases of saddle embolus (E). Consolidation of an entire lobe is more consistent with lobar pneumonia (A). Fluffy bilateral infiltrates seen on plain films are suggestive of pulmonary edema (B).

✓ 14. Answer D

The most common ECG finding in patients with PE is sinus tachycardia. S1Q3T3 (C) refers to a deep S wave in lead I, Q wave in III, and inverted T wave in III, and although it is considered a "classic" finding for PE, it is neither sensitive nor specific and found in only 20% of patients. When pulmonary arterial pressures get high, ECG findings may

demonstrate right ventricular strain (A). The remaining answer choices can all occur in patients with PE but appear infrequently (B–C, E).

✓ 15. Answer A

The most common acid/base abnormality seen initially in patients with PE is uncompensated respiratory alkalosis. Patients with PE can have hypoxia, and the physiologic response to this is hyperventilation which results in a primary decrease in PCO_2 (hypocapnia). Acute respiratory alkalosis causes light-headedness, confusion, peripheral paresthesias, cramps, and syncope. Eventually patients will have a compensated respiratory alkalosis as the body's excess HCO_3^- is buffered by extracellular hydrogen ion. Combined respiratory alkalosis and metabolic acidosis is seen initially in patients that have ingested a large amount of aspirin (E).

✓ 16. Answer E

The vast majority of fevers within the first 24 h of surgery are noninfectious in origin and are due to release of cytokines, not atelectasis as commonly stated (but before you challenge your chief residents, look it up for yourself!). However, atelectasis is the most common pulmonary complication following surgery. Postoperative wound infections typically do not occur until around the seventh postoperative day. There are rare exceptions. Group-A beta-hemolytic *Streptococcus* and *Clostridium* are known to rarely cause devastating early (sometimes within hours) postoperative wound infections. For this reason, when a patient spikes a fever, always perform a directed physical exam, including looking at the wound. Clues to a wound infection include a warm, erythematous, painful wound with dishwater (grayish) foul-smelling discharge. Management consists of immediate broad-spectrum IV antibiotics (including high-dose clindamycin to decrease alpha-toxin produced by *Clostridium*) and a prompt return to the operating room for aggressive wound debridement. Reassurance, bedside drainage, and antibiotics alone would not be appropriate (A–C). Reclosure of the fascia would be appropriate for fascial dehiscence (D). However, fascial dehiscence presents with a large volume of serous-colored fluid draining from the wound, not with fever and evidence of wound infection.

✓ 17. Answer E

The patient is in shock. The most likely etiology of the shock in this setting is hypovolemic shock, most likely from bleeding (in this case most likely the ligation of the splenic artery has come off). Massive postoperative bleeding after surgery is rare and can be difficult to recognize. It can present as oliguria and differentiating bleeding from other causes of hypotension and oliguria can be difficult. Lab values such as hemoglobin and hematocrit are not useful in detecting acute hemorrhage in the postoperative setting. It generally takes 8–12 h for interstitial fluid to redistribute into the vascular space, and blood concentration will initially appear unchanged. This patient's hemoglobin/hematocrit has shown a significant drop, and in combination with his thirst, pale skin, mechanism of injury, and hemodynamic instability, he is most likely suffering from internal bleeding and will need to return to the operating room. CT scan would be inappropriate for a patient with hemodynamic instability (A). An ECG, DPL, or a chest x-ray (the breath sounds are clear) is unlikely to be of value (B–D). Failure to recognize bleeding has fatal consequences. An adjunct while preparing for immediate return to the operating room would be to perform a bedside ultrasound (to look for fluid), if available.

Trauma

Dennis Y. Kim

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Abdominal Pain Following Motor Vehicle Collision

Areg Grigorian, Alexis L. Woods, Christian de Virgilio, and Dennis Y. Kim

Case Study

A 35-year-old unrestrained male driver is brought in by paramedics following a motor vehicle collision (MVC). There were extensive passenger space intrusion and significant steering wheel deformity. On arrival to the emergency department, the patient is conscious and responsive. His blood pressure is 80/40 mmHg and heart rate is 110/min. His pupils are equal, round, and reactive to light. His breathing is shallow but he is able to protect his airway. Breath sounds are clear bilaterally. His abdomen is distended and mildly tender to palpation, without rebound or guarding. He has blood at the urethral meatus. There are no obvious deformities in his extremities.

Diagnosis**Is This Patient in Shock? What Are the Different Types of Shock?**

Yes. Shock is a state in which there is inadequate utilization of oxygen needed for aerobic metabolism, leading to hemodynamic instability and end-organ dysfunction. Although there is no precise blood pressure cutoff that defines shock, hypotension (a blood pressure below 90 mmHg) in a trauma patient is due to hypovolemic/hemorrhagic shock until proven otherwise. Other less common causes of shock (■ Table 42.1) in the trauma patient are obstructive shock and neurogenic shock.

History and Physical Exam**What Are the Clinical Manifestations of Hypovolemic Shock?**

Clinical manifestations of shock include tachycardia (*initial sign*), hypotension, pale and cool extremities, weak peripheral pulses, prolonged capillary refill (>2 seconds), low urine output, and altered mental status.

Watch Out

Pediatric patients can have significant hypovolemia from hemorrhage but still maintain normal blood pressure, owing to a strong vascular tone; tachycardia may be only clue.

Watch Out

Older patients can be in hypovolemic shock but still maintain a seemingly normal blood pressure (as they may be hypertensive at baseline) and heart rate (as they may be receiving beta blockers). Always review home medications.

What Is the Significance of Blood at the Urethral Meatus?

Blood at the urethral meatus in men, in the setting of blunt trauma, is highly suggestive for a urethral injury (such an injury is rare in women) as a result of a pelvic fracture. Other signs of urethral injury include perineal ecchymosis, scrotal hematoma, and a high-riding (non-palpable) prostate on digital rectal examination. Placing a urinary catheter (Foley) is contraindicated due to the risk of worsening a partial or complete urethral injury. Radiographic imaging (via a retrograde urethrogram {RUG}) should be performed first to confirm that the urethra is intact.

Watch Out

In women with a pelvic fracture, the fracture can lacerate the vagina, creating an open fracture. Don't assume vaginal blood is due to menses. Such an injury can easily be overlooked without a pelvic exam.

■ Table 42.1 Types of shock in the trauma setting

Type of shock	Clinical scenario	Mechanism	CVP	SVR	CO	PCWP
<i>Hypovolemic</i>	Any blunt or penetrating trauma with hemorrhage; burns	Decreased blood and plasma volume	Low	High	Low	Low
<i>Obstructive</i>	Blunt cardiac injury, cardiac tamponade, tension pneumothorax, pulmonary embolus	Failure of myocardial pump (blunt cardiac injury), decreased preload (cardiac tamponade, tension pneumothorax)	High	High	Low	High
<i>Neurogenic</i>	High cervical spinal cord injury, warm well-perfused extremities, normo-/bradycardic (different from other types of shock), priapism	Autonomic dysfunction (loss of sympathetic tone) with peripheral vasodilation	Low	Low	Low	Low

CVP central venous pressure, SVR systemic vascular resistance, CO cardiac output, PCWP pulmonary capillary wedge pressure

What Is the Significance of Gross Hematuria?

Gross hematuria following blunt trauma strongly suggests an injury to the kidney or bladder. Renal injury is ruled out via a CT of the abdomen/pelvis with IV contrast. An injury to the bladder is best determined by either a CT cystogram or a retrograde cystogram.

Watch Out

Intraperitoneal rupture of the dome of the bladder can occur in the absence of a pelvic fracture. Such patients typically are involved in a high-speed MVC and have a full bladder (e.g. drinking at the bar).

Watch Out

Intraperitoneal bladder injuries are generally managed with open repair, whereas extraperitoneal injuries are most often managed nonoperatively with bladder catheter (Foley) drainage alone.

Pathophysiology

How Much Blood Loss Is Necessary to Cause Hypotension (as in the Patient Above) in the Supine Position?

Hypotension in the supine position implies the patient has lost at least 30–40% of his blood volume (Class III shock; see ■ Table 42.2), which represents 1500–2000 ml of blood.

What Are the Five Main Sources of Major Blood Loss in Blunt Trauma?

The main sources are chest, abdomen, pelvis/retroperitoneum, long bones, and “street” or external.

What Are the Most Likely Injuries in Each of These Locations that Would Lead to Major Blood Loss?

Given that hypotension in the supine position implies a blood loss of 1500–2000 ml, the clinician must consider what injuries might lead to such a large blood loss and the likely locations of such occult blood loss. In the chest, a massive hemothorax from a laceration of the lung or bleeding from torn intercostal arteries (both due to a rib fractures) is a leading cause. The liver is the most commonly injured organ following blunt abdominal trauma, but massive blood loss is most often due to splenic rupture. Massive retroperitoneal bleeding is most often due to pelvic fractures that tear small arterial branches off the internal iliac artery or pelvic veins. Renal trauma can also cause major retroperitoneal hemorrhage. Blunt injury to the abdominal aorta and inferior vena cava are exceedingly rare. A femur fracture can lead to a loss of one or two units of blood (each unit is about 500 ml). Thus, bilateral femur fractures may lead to hypotension. Though often overlooked, because of its rich blood supply, large scalp lacerations can surprisingly lead to major external blood loss.

Watch Out

Rapid deceleration injuries can lead to a transection of the descending aorta (distal to the ligamentum arteriosum), which is often fatal. Suspect the injury if the mediastinum is wide on chest x-ray.

■ Table 42.2 Shock Classes I–IV

	Class I	Class II	Class III	Class IV
<i>Blood loss (% blood volume)</i>	Up to 750 ml (<15%)	750–1500 ml (15–30%)	1500–2000 ml (30–40%)	>2000 ml (>40%)
<i>Heart rate</i>	Normal	Tachycardia (100–120/min)	Tachycardia (>120/min)	Tachycardia (>120/min)
<i>Blood pressure</i>	Normal	Normal to minimal change	Significantly decreased (SBP < 90 mmHg)	Significantly decreased (SBP < 90 mmHg)
<i>Pulse pressure</i>	Normal or increased	Decreased	Decreased	Decreased (<25 mmHg)
<i>Respiratory rate</i>	Normal	Tachypnea	Tachypnea	Tachypnea

SBP systolic blood pressure

What Cavity Should Not Be Considered to Be the Source of Hemorrhagic Shock and Why?

A closed-head injury should not be considered the source of hypovolemic shock (cannot lose that much blood into the cranium). In fact, a severe closed head may induce the *Cushing reflex* (hypertension, bradycardia, irregular respirations) via a sympathetic response causing peripheral vasoconstriction in order to maintain adequate blood pressure and regulate perfusion to the brain. As a result of the vasoconstriction, the baroreceptors respond with increased parasympathetic stimulation of the heart, causing bradycardia. This reflex is seen in patients with increased intracranial pressure (ICP) and often heralds brain herniation.

Initial Management

What Are the ABCDE of Trauma Patient Management?

The sequence of evaluation creates a prioritization based on the highest likelihood for risk of death and disability. The initial evaluation makes up the *primary survey* for trauma patients. Although presented as a sequential algorithm, elements of the primary survey often occur simultaneously.

Airway with C-spine precaution: Severely injured patients can develop airway obstruction leading to inadequate ventilation and hypoxia within minutes. As a result, airway evaluation and management are the first step in the assessment of the severely injured patient. A Glasgow Coma Scale (GCS) of 8 or less is an indication to secure the airway with an endotracheal tube (remember: if it's 8, intubate).

Breathing: Once the airway has been secured, it is important to assess the adequacy of oxygenation and ventilation. Inspect the chest wall looking for symmetrical chest movement and signs of injury, auscultate breath sounds bilaterally, and palpate for crepitus or chest deformity.

Circulation: Once the airway is secured and oxygenation is established, it is important to perform an initial evaluation of the patient's circulatory status, which starts with palpation of pulses. As a rough guide, if the radial pulse is palpable, then the systolic pressure is at least 80 mmHg. If the carotid or femoral pulses are palpable, then systolic is at least 60 mmHg. Establish peripheral vein access with two large-bore (16 gauge or larger) IVs in the upper extremities, and begin fluid resuscitation if necessary.

Disability (neurologic evaluation): The next step is to perform a focused neurological examination. The exam starts off by assessing the patient's level of consciousness using the Glasgow Coma Scale (GCS). The GCS is composed of three facets: eye, verbal, and motor responses (reviewed in ► Chap. 29)

Exposure and environmental control: During the primary survey, it is important that the patient is completely exposed to assess for injuries in discrete areas such as the scalp, axillae, and perineal areas. Warming blankets can be used to keep the patient warm.

Watch Out

The FAST scan is to be performed after the primary or secondary survey and is appropriate in patients presenting with hypotension or penetrating trauma to the cardiac box, as the decision to go to the OR is emergent. However, FAST scan should not delay securing vascular access, and in the stable patient, FAST should not delay the timely performance of a secondary survey.

What Is Included in the Secondary Survey of Trauma Patients?

The primary survey should be done completely and quickly before moving on to diagnostic adjuncts and the secondary survey (history and detailed physical examination). If the patient is conscious and able to speak, a quick AMPLE history should be obtained (Allergies, Medications, Past medical history, Last meal, Events preceding the trauma). A careful and systematic head-to-toe physical exam should be done to ensure that nothing has been overlooked and to identify all major injuries.

What Is the First Step in the Management of the Patient Presented?

The patient is presenting with hypotension after blunt trauma. His airway is secure. He should have two large-bore IVs started and receive 2 liters of crystalloid. If the blood pressure does not promptly respond, the patient should immediately be given blood products. Since the patient is hypotensive, a FAST scan should be performed to look for bleeding in the abdomen (it is a quick assessment and will not significantly delay operative intervention). In addition, the operating room should be notified as this patient will need to be emergently taken for an exploratory laparotomy.

What Type of Airway Is Recommended in the Trauma Setting?

Orotracheal intubation is the most common method of securing an airway. In the trauma setting, this is performed using rapid sequence intubation (RSI) with C-spine protection. RSI is designed to prevent aspiration in patients who

have not been fasting. Rather than slowly titrating drugs to effect while utilizing bag-valve-mask ventilation (“bagging”), RSI involves administering immediate weight-based doses of sedatives (etomidate) and neuromuscular blocking agents in quick succession without “bagging.” Since the trauma patient should be presumed to have a C-spine injury until proven otherwise, intubation must be performed with strict in-line cervical immobilization. This is a two-person technique.

What Are the Two Types of Surgical Airways? Which One Is More Appropriate in the Emergent Trauma Setting?

The two surgical airways are cricothyrotomy (also called cricothyroidotomy) and tracheostomy. Cricothyrotomy is the surgical airway of choice in the emergency setting. This is because it is easier and faster to perform with fewer complications. Indications include severe facial trauma, angioedema, failed orotracheal intubation, and upper airway obstruction. An incision is made through the cricothyroid membrane, which is located between the thyroid (superior) and cricoid (inferior) cartilages. Cricothyrotomy is not generally a good long-term airway, as there is a tendency to develop subglottic stenosis. Tracheostomy (through the tracheal rings) is more time-consuming to perform, requires significant expertise, and is therefore performed in a more elective setting. It is the surgical airway of choice for long-term management. Indications include malignancies causing upper airway obstruction and long-term need for mechanical ventilation (due to inability to wean).

Why Is Nasotracheal Intubation Not Recommended in the Trauma Setting?

Trauma patients may have facial and basilar skull fractures. Attempts at nasotracheal intubation may lead to inadvertent intracranial passage of the nasotracheal tube.

How Does One Confirm Proper Intubation?

Clinical indicators (e.g., condensation of tube with ventilation, adequate breath sounds on auscultation) alone cannot be relied upon to confirm proper endotracheal placement. Confirmation of proper endotracheal tube placement is done by end-tidal CO₂ determination (capnography) and considered the gold standard. A chest X-ray is subsequently performed to confirm that the endotracheal tube is not advanced too far in the tracheobronchial tree (i.e., past the carina).

Watch Out

End-tidal CO₂ determination is not accurate for ensuring proper endotracheal tube placement if a patient is in cardiac arrest. In such cases, the only practical option is to confirm placement by auscultating breath sounds.

Where Should the Peripheral IV Lines Be Placed?

Preferably one IV should be placed in each antecubital fossa. However, the placement should take into consideration potential sources of active hemorrhage. For example, if a patient has significant arm trauma, the IVs should be placed in a non-injured upper and/or lower extremity.

Is a Central Line Preferred over a Peripheral IV for Trauma Patients?

Peripheral IVs are preferred over central lines in the setting of trauma. Central lines (subclavian, internal jugular) require more time to place and are associated with more risks (iatrogenic pneumothorax), especially in the hypovolemic patient (central veins are collapsed). Peripheral IVs provide less resistance to flow, given the shorter length of the catheter. A large bore and shorter central line (called a sheath introducer or cordis) is indicated if peripheral access is problematic and in the hemodynamically unstable patient. It is generally placed in the femoral vein.

Watch Out

If peripheral access is unobtainable, a line can be placed in an intraosseous location (preferably tibial).

What Is the Ideal Fluid Resuscitation in Trauma?

In patients presenting with hemorrhagic shock, 2 liters of crystalloid should be infused. Normal saline (NS) and lactated Ringers (LR) are the preferred crystalloids in the trauma setting. Sodium is the main extracellular ion and as such is responsible for maintaining tonicity of the blood. NS contains only sodium and chloride (154 meq/l). LR is considered more physiologic (130 meq/l of Na, 109 meq/l of Cl, 28 meq of lactate, 4 meq/l of potassium, and 3 meq/l of calcium). The lactate is converted to bicarbonate by the liver and thus provides buffering. One to two liters of fluid should be rapidly

administered in the initial resuscitation. In non-responders, the ideal resuscitation involves the use of blood products (type O negative packed red blood cells {PRBCs} if type specific is not yet available). Once type-specific PRBCs are available, they are administered in a 1:1:1 ratio in conjunction with fresh frozen plasma (FFP) and platelets.

Why Are Large Doses of K + Not Given in the Initial Resuscitation?

Due to severe hemorrhage, trauma patients may be in shock, which leads to a decreased renal perfusion, a decreased glomerular filtration, and therefore, a decreased ability to excrete excess potassium. Trauma patients are at risk of developing hyperkalemia due to crush injuries. Since potassium is the main intracellular ion, such injuries may result in muscle cells releasing potassium. Of note, the amount of K + in LR is considered physiologic and is therefore considered acceptable.

What Is Colloid? What Is the Theoretical Benefit? Any Actual Benefit in Trauma Resuscitation?

Colloids contain larger molecules that are insoluble, such as albumin, in addition to water and electrolytes. The theoretical benefit is that such large molecules do not freely diffuse across a semipermeable membrane, thus preserving intravascular osmotic pressure. In actuality, however, colloids have not been shown to be of benefit, are more expensive, and, in patients with traumatic brain injury, have been shown to be harmful.

After Appropriate Fluid Resuscitation Is Started, What Must Be Done Next?

The source of bleeding must quickly be identified and stopped. Most often, a patient with hemorrhagic shock will require immediate transport to the operating room (OR). Prior to taking the patient to the OR, however, an attempt should be made to determine if the bleeding is coming from the chest, abdomen, pelvis, or other source. If the patient is awake and alert and is exhibiting symptoms and signs of peritonitis, then an exploratory laparotomy is performed (without need for a FAST scan). If, on the other hand, the patient is unresponsive, or is not exhibiting signs of peritonitis, a focused assessment with sonography for trauma (FAST scan) is rapidly performed to look for fluid in the peritoneal cavity. If the FAST scan is positive, the patient is taken to the OR for an exploratory laparotomy. In addition, an X-ray of the chest is obtained to look for a massive hemothorax. In such a case, a tube thoracostomy (chest tube) is inserted. A

pelvic radiograph is obtained to determine if there is a pelvic fracture that requires immediate stabilization with external fixation or binding. Further bleeding from a pelvic fracture is most often managed by embolization by interventional radiology (assuming the patient can be stabilized). CT scan is *contraindicated* in the unstable patient.

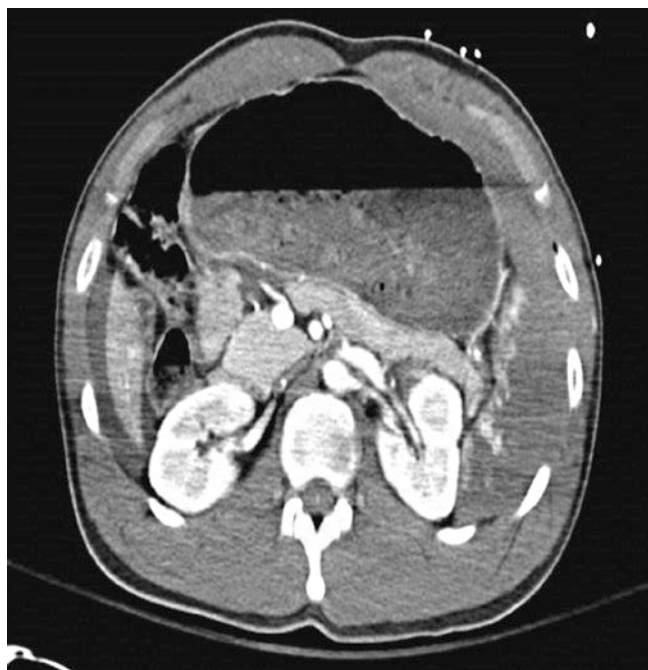
What Is the Role of Diagnostic Peritoneal Lavage (DPL) in the Trauma Patient?

DPL has very limited use. In the stable patient, CT scan is preferred. In the unstable patient, FAST scan has largely replaced DPL in most trauma centers. DPL is indicated in the unstable patient with either an equivocal FAST scan or if FAST scan is not available. With DPL, a small abdominal incision is made under local anesthesia, and a catheter is inserted into the peritoneal cavity. The test actually begins with a peritoneal aspiration (termed diagnostic peritoneal aspiration {DPA}). If more than 20 cc of gross blood is aspirated, the study is considered positive, lavage is not necessary, and the patient is transported directly to the OR. If no blood is detected, the clinician may choose to perform a lavage of the peritoneal cavity with 1 liter of normal saline. DPL is positive if there are more than 100,000 RBCs/mm³ identified by biochemical analysis of the lavage effluent. Some surgeons choose to only do the DPA, as it is unlikely that the peritoneum is the source of massive hemorrhage if the DPA is negative, and the fluid inserted into the peritoneal cavity may confound subsequent CT scans. DPA, like FAST scan, is not capable of detecting retroperitoneal bleeds.

Subsequent Management

What Is the Management of Intra-abdominal Bleeding Due to Splenic Injury?

The most common cause of intra-abdominal *bleeding* following blunt trauma is splenic injury (■ Fig. 42.1) (the most commonly injured organ is the liver). For *hemodynamically stable* patients with evidence of a splenic injury (based on FAST or CT scan) and no other indication for exploratory laparotomy, the management depends on the severity of the splenic injury. Low-grade injuries can be managed with observation. Higher-grade injuries (active extravasation) are best managed with splenic embolization, if the appropriate interventional radiology personnel and resources are available. For hemodynamically unstable patients, the recommended management is surgical exploration and splenectomy or splenorrhaphy (repair of the spleen). In patients with splenic injuries that require a splenectomy, they must be vaccinated for *Streptococcus pneumoniae* and other encapsulated bacteria (*Haemophilus influenza* type-B and *Neisseria meningitidis*), ideally 2 weeks after surgery.



■ Fig. 42.1 Axial CT showing a ruptured spleen with free fluid around the liver from blunt abdominal trauma

Watch Out

Kehr's sign is an acute referred pain in the left shoulder due to splenic injury.

Watch Out

Blunt splenic injury may present with tenderness to palpation of the left upper quadrant and pleuritic chest pain. In hemodynamically stable patients with blunt trauma, a CT scan should be performed to rule out splenic injury with this presentation.

What Is the Management of Intra-abdominal Bleeding Due to Liver Injury?

The most commonly injured organ after blunt trauma is the liver (■ Fig. 42.2). Most patients with liver injury can be managed nonoperatively. If the patient is stable but demonstrates ongoing bleeding, embolization via interventional radiology is an accepted therapeutic adjunct. If the patient is unstable, surgical exploration is necessary. Bleeding from most liver injuries can be stopped intraoperatively using a combination of perihepatic packing (with laparotomy pads), cauterization, and/or suturing. This may stabilize the patient sufficiently to then perform embolization. If bleeding cannot be stopped, the laparotomy packs are sometimes left in situ for 24–48 hours.



■ Fig. 42.2 Axial CT showing severe blunt liver trauma as evidenced by regions of hypoenhancement suggesting laceration and/or vascular compromise

Watch Out

During surgery for liver injury, the Pringle maneuver (clamping the portal triad) is utilized to temporarily control bleeding from hepatic artery or portal venous sources. Failure of the Pringle maneuver to stop bleeding implies that the bleeding is coming from the hepatic veins.

What Are the First Steps in the Management of Patients with a Pelvic Fracture? What Is the Subsequent Management?

In addition to initial blood or fluid resuscitation, if a patient with a pelvic fracture demonstrates evidence of ongoing bleeding, they should have their pelvic volume reduced by wrapping a pelvic binder or sheet around the greater trochanters of the femurs. If other sources of bleeding have been ruled out (i.e., a FAST exam is negative for free fluid in the abdomen, and chest X-ray is negative), the patient should undergo diagnostic and therapeutic angiography with embolization.

Watch Out

Military antishock trousers (MAST suits) or pneumatic antishock garments are different than using a pelvic sheet. MAST suits markedly increase systemic vascular resistance and have not been shown to be effective for pelvic fractures.

Areas You Can Get in Trouble

Failing to Recognize the Significance of Free Fluid in the Peritoneal Cavity When There Is No Solid Organ Injury

Free fluid in the abdomen after blunt trauma is most often due to bleeding and is most often associated with an obvious injury to the spleen (most common) or liver. In the absence of major organ injury, free fluid may represent bleeding from a more occult source (such as a mesenteric artery), enteric contents (from a small bowel injury), or urine (from a bladder rupture).

Treating Hypovolemic Shock Initially with Vasopressors

The early use of vasopressors in the management of hemorrhagic shock is not recommended and may even be harmful in patients that have not been adequately resuscitated. Hypotension in the setting of trauma is usually due to hemorrhagic shock. Treatment is to give volume and identify and stop the source of hemorrhage. Patients with hypovolemic shock have a very high systemic vascular resistance due to vasoconstriction, which decreases perfusion to vital organs. Adding a vasopressor early on will only serve to aggravate the situation.

Area of Controversy

Management of a Pelvic Fracture in a Hemodynamically Unstable Patient

Most surgeons recommend angiographic embolization for ongoing bleeding from a pelvic fracture. However, if the patient is truly in severe shock, they may not be able to wait until an interventional radiologist is called in to perform such a procedure. As such, some trauma surgeons recommend taking the patient to the operating room for preperitoneal packing (to temporarily tamponade bleeding) followed by angiographic embolization. Ligation of bilateral internal iliac arteries is another option in lieu of angiographic embolization.

Summary of Essentials

Diagnosis

- Types of shock in the trauma setting:
 - Hypovolemic: blunt/penetrating trauma with hemorrhage, burns
 - Cardiogenic: blunt cardiac injury, arrhythmias, cardiac tamponade
 - Neurogenic: high cervical spinal cord injury, warm well-perfused extremities

History and Physical Exam

- Clinical manifestations of shock:
 - Tachycardia (initial sign), hypotension, pale and cool extremities, weak peripheral pulses, prolonged capillary refill (>2 seconds), low urine output, altered mental status
- Blood at urethral meatus may indicate urethral injury; Foley catheter contraindicated.

Pathophysiology

- Hypotension in supine position indicates 30–40% loss of blood volume (Class III).
- Five main sources of blood loss: chest, abdomen, pelvis/retroperitoneum, long bones, and “street” or external.
- Closed-head injury is never a source of hypovolemic shock.

Initial Management

- Start with ABCs.
- Orotracheal intubation is the most common method of securing an airway:
 - RSI and C-spine protection
 - Nasotracheal intubation is not recommended
- Two surgical airways:
 - Cricothyrotomy/cricothyroidotomy
- Emergent airway of choice:
 - Fast but not good long term:
 - Tracheostomy
 - Not for trauma as too time-consuming.
 - Airway of choice for long term.
- Peripheral IVs are preferred over central lines in setting of trauma:
 - LR or NS is the preferred crystalloids; no role for colloids.
 - Blood products needed for non-responders or transient responders.
- Directly to OR if peritonitis is present.
- FAST scan in unstable patient:
 - DPL if equivocal FAST scan or if FAST scan is not available
- CT scan in stable patients.

Subsequent Management

- Splenic injury:
 - Observation if stable and not bleeding
 - Splenic embolization for hemodynamically *stable* patients with blush on CT
- Surgical exploration and splenectomy or splenorrhaphy for hemodynamically *unstable* patients with splenic injury:
 - Vaccinate for encapsulated bacteria ideally 2 weeks following splenectomy or prior to discharge from hospital

- Liver injury:
 - Most are managed nonoperatively.
 - Hemodynamically stable with ongoing bleeding require embolization.
 - Hemodynamically unstable with ongoing bleeding require surgical exploration.
- Pelvic fracture:
 - Pelvic angiography and embolization if ongoing bleeding and appropriate personnel and resource immediately available
- The early use of vasopressors is not recommended and may even be harmful in patients that have not been adequately resuscitated.

Suggested Reading

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Watch Out

- Free fluid in abdomen without solid organ injury may represent bleeding from a more occult source (such as a mesenteric artery), enteric contents (from a small bowel injury), or urine (from a bladder rupture):



Penetrating Abdominal Trauma

Jeffry Nahmias, Areg Grigorian, and Dennis Y. Kim

Case Study

A 24-year-old male is brought to the emergency room following a gunshot wound (GSW) to the left lower abdomen. On initial examination his blood pressure is 80/65 mmHg, heart rate is 140/min, and respiratory rate is 26/min. He is pale, diaphoretic, and writhing in pain. The patient's airway is patent, and there are equal breath sounds bilaterally. He has a rigid abdomen with diffuse tenderness, guarding, and rebound. There is a single GSW to the left lower quadrant. Palpation of the patient's groin reveals pulses are bilaterally weak but symmetrical.

Diagnosis**What Is the Most Likely Diagnosis?**

Given that this patient presents with penetrating abdominal trauma, he is most likely in hemorrhagic shock secondary to bleeding in the peritoneal cavity. This is supported by his hemodynamic instability (decreased systolic blood pressure, narrowed pulse pressure [defined as ≤ 30 mmHg], and tachycardia). Peritonitis on physical exam (e.g., rigid abdomen, diffuse tenderness, rebound) supports the presence of a hollow viscus or bowel injury.

History and Physical**What Is the MIVT Prehospital Report?**

Mechanism, Injuries, Vitals, and Treatment

What Are the Two Most Common Types of Penetrating Trauma?

Penetrating trauma refers to injuries caused by a foreign object that enters or penetrates tissues. Stab wounds and GSWs are the two most common forms of penetrating injuries. Stab wounds are low velocity and low kinetic energy injuries in which tissue damage is isolated to the pathway of potential penetration, resulting in localized injuries. Smaller caliber handguns deliver a lower velocity injury, whereas high-power assault weapons can cause high-velocity injuries. The latter is more likely to result in tissue damage in areas remote from the bullet track.

Watch Out

Careful exposure and examination of the entire patient is critical to avoid missing penetrating injuries, including rolling the patient to look at their back (while maintaining C-spine precautions). The perineum and axilla should always be examined for evidence of occult injury.

What Three Physical Exam Findings Independently Mandate Immediate Operative Intervention in Patients with Penetrating Abdominal Trauma?

The three physical exam findings are shock, peritonitis, and evisceration. Prior to surgery, chest and abdominal X-rays should be performed provided that the patient remains stable (the patient above though is not stable). Such plain films can provide useful information about the trajectory or path of bullets and potential injuries. This patient has two of these findings (shock and peritonitis), either of which are indications for an exploratory laparotomy.

What Is a Tangential GSW? Do Patients with Findings of a Tangential GSW Require Any Further Workup?

Not all GSWs to the abdomen automatically mandate surgery. Tangential GSWs are injuries that have identifiable entry and exit wounds without clinical evidence of injury to deeper structures. Prior to simply dismissing such injuries as benign, however, it is important to recognize that tangential GSWs may be associated with significant blast effect or fragmentation. This may result in delayed injury to underlying tissues, vessels (e.g. pseudoaneurysm), and organs. Patients with tangential GSWs should undergo further workup in the form of contrast-enhanced CT scan and/or serial physical examinations according to local institutional protocols.

Anatomy**What Are the Borders of the Anterior Abdomen, Flank, Back, and Thoracoabdomen? (Table 43.1)**

Table 43.1

Location	Borders
<i>Anterior abdomen</i>	Xiphoid and costal margins superiorly, the anterior axillary lines laterally, and the inguinal ligaments and pubic symphysis inferiorly
<i>Flank</i>	Between anterior and posterior axillary lines from the level of the sixth intercostal space to the iliac crest
<i>Back</i>	Tips of the scapular superiorly, posterior axillary lines laterally, and the iliac crests inferiorly
<i>Thoracoabdomen</i>	Nipple (4th intercostal space) to costal margin, anterior to posterior axillary lines

What Is the Significance of Injuries to the Thoracoabdominal Region?

Injuries to the thoracoabdominal regions can damage thoracic or abdominal structures including the diaphragm.

What Three Distinct Regions Comprise the Internal Abdomen?

The three distinct regions are peritoneal cavity, pelvis, and *retroperitoneum*.

Watch Out

A penetrating wound below the 4th intercostal space (nipple line) may traverse the diaphragm and the peritoneal cavity, as such laparoscopy and/or laparotomy are generally indicated.

Why Is It Difficult to Diagnose Injuries to Retroperitoneal Organs in Trauma Patients?

Injuries to retroperitoneal organs may not manifest with symptoms and signs of peritonitis due to their protected location. In addition, the focused assessment with sonography for trauma (FAST) exam is notorious for missing retroperitoneal bleeding.

Retroperitoneal Organs/Structures

- Duodenum (second to fourth parts)
- Pancreas
- Kidneys
- Ureters

- Bladder
- Ascending colon (posterior wall)
- Descending colon (posterior wall)
- Rectum (distal)
- Aorta, inferior vena cava, iliac veins

What Is the Zone Classification for Retroperitoneal Hematomas and How Does the Location Affect Management?

Retroperitoneal hematomas are classified into three zones to serve as a reminder as to what vascular structures may be injured and helps guide intraoperative management. The ultimate decision as to whether to explore a retroperitoneal hematoma is based upon the hemodynamic status of the patient, the mechanism of injury, the zone location, and in some instances whether it is expanding or pulsatile (■ Table 43.2).

What Are the Two Most Common Organs Injured Following a Penetrating Abdominal Injury?

The two most common organs injured are the *small bowel* followed by the liver.

What Injuries Must Be Ruled Out with GSWs That Travel Across the Pelvis?

Transpelvic GSWs are associated with injuries to various organ systems including vascular (iliac vessels), genitourinary (bladder, ureters, uterus, vagina), and gastrointestinal (small bowel, colon, rectum). In stable patients with a transpelvic GSW, a contrast-enhanced CT scan of the abdo-

■ Table 43.2 Retroperitoneal zones

	Zone 1	Zone 2	Zone 3
Location	Upper midline/central	Upper lateral	Lower midline/pelvic
Vascular structures	Aorta and its branches (celiac, SMA, proximal renal artery), IVC, SMV	Renal artery and vein	Common/internal/external iliac arteries and veins
Mechanism			
Blunt	Explore	Selective	Do not explore ^a
Penetrating	Explore	Explore ^b	Explore

SMA superior mesenteric artery, IVC inferior vena cava, SMV superior mesenteric vein

^aIn patients with shock or hemodynamic instability and evidence of an expanding or pulsatile Zone 3 hematoma following blunt trauma, consideration may be given to exploring the hematoma (with or without bilateral internal iliac artery ligation)

^bIf non-expanding, and directly over kidney, these can sometimes be observed, as exploration and opening Gerota's fascia may lead to more bleeding

men and pelvis should be performed. Consideration should be given to performing a proctoscopy to rule out injury to the rectum. Females should undergo a vaginal examination.

Workup

What Initial Workup Is Recommended for the Above Patient?

No workup is needed in this patient as he has clear indications for surgical intervention (both peritonitis and hemodynamic instability/shock following penetrating trauma). He should be taken directly to the operating room.

In the Absence of Shock, Peritonitis, or Evisceration, What Imaging Is Recommended for a Patient with Penetrating Abdominal Trauma?

CT of the abdomen and pelvis with intravenous contrast. If concern exists for multi-cavitary torso trauma, a CT chest should also be obtained.

Are Diagnostic Peritoneal Lavage (DPL) and FAST Helpful Studies in Patients with Penetrating Abdominal Trauma?

The FAST exam is more useful for patients following blunt trauma. Its primary utility for penetrating abdominal trauma is to rule out cardiac tamponade (for thoracoabdominal injuries). Aside from this, the utility of FAST for penetrating abdominal trauma is limited. Similarly, DPL, which is rarely performed today, is more useful for blunt abdominal trauma, particularly if FAST is unavailable or equivocal and the patient's hemodynamic is such that transfer to the CT scanner may be unsafe (i.e., presence of hemodynamic instability).

Watch Out

The FAST exam is not helpful in identifying injury to retroperitoneal structures.

Is There a Role for Local Wound Exploration for Penetrating Abdominal Injury?

Local wound exploration may be performed in patients with anterior stab wounds (not flank) but only if performed by an experienced surgeon in a patient who does not have an indication for immediate surgery. The goal of local wound exploration is to determine if the injury has penetrated the anterior

fascia. If it has not, surgery can be avoided. Violation of the anterior fascia is an indication for either an exploratory laparotomy or diagnostic laparoscopy to assess for peritoneal violation and rule out injury to the abdominal viscera.

Initial Management

What Are the First Steps in the Management of This Patient?

Initial management of the trauma patient always begins with the primary survey to identify and treat immediately life-threatening conditions. The primary survey involves assessing the ABCDEs (airway with cervical spine precautions, breathing, circulation {with hemorrhage control}, disability, and exposure/environment). With penetrating injuries, attention should be directed to identifying the presence and location of all wounds. If the patient is stable, it may be helpful to place radiopaque markers over these sites prior to radiologic imaging to help reconstruct the path or trajectory of bullets.

What Is a Massive Transfusion Protocol (MTP)? When Should It Be Initiated?

MTP is an institutional protocol which is activated in patients with life-threatening hemorrhage or exsanguination. The primary purpose of a MTP is to provide blood component therapy (packed red blood cells [PRBCs], plasma, and platelets) early during the resuscitation, in a systematic, rapid, and efficient manner. By administering blood components early, the goal of a MTP is to prevent the development of dilutional coagulopathy and hypovolemia. In the setting of massive hemorrhage, MTP has replaced the traditional resuscitation approach, which began with large volumes of crystalloid (lactated Ringers or normal saline) followed by PRBCs. Under a MTP, the ratio of plasma/platelet/PRBC is often given in a 1:1:1 or 1:1:2 manner. Determination of whether to initiate a MTP is ultimately based on clinical judgment. A good clinical scoring tool is the ABC score, which recommends MTP if the patient has any two of the following: penetrating mechanism, systolic blood pressure ≤ 90 mmHg, heart rate ≥ 120 /min, or positive FAST exam.

What Is Permissive Hypotension?

Permissive hypotension is a resuscitation strategy used in patients with penetrating torso trauma to limit further blood loss. In the past, patients with penetrating trauma and hypotension were aggressively resuscitated with crystalloids with the overall goal of restoring a "normal" blood pressure. Permissive hypotension is based on the concept of avoiding "popping the clot." Several studies have challenged the practice of overly aggressive fluid replacement, arguing that it will lead to more bleeding by raising the blood pressure and

creating a dilutional coagulopathy and that it does not address the source of bleeding. Some clinicians now elect to limit fluid resuscitation and permit mild hypotension (in the setting of penetrating trauma) at least until hemorrhage is controlled.

Watch Out

Permissive hypotension is only applicable to patients with penetrating torso trauma (as well as ruptured AAA). This strategy should not be employed in patients with blunt trauma, especially in the presence of a head injury.

Should Empiric Antibiotics Be Routinely Administered to All Patients with Penetrating Trauma?

No. There is no indication to administer empiric antibiotics to patients with penetrating trauma. Patients with clear indications for surgical intervention on initial exam (e.g., peritonitis, hemodynamic instability) should receive preoperative antibiotics to cover skin and bowel flora.

Should Tetanus Prophylaxis Be Routinely Administered to Patients with Penetrating Trauma?

No. Only patients with <3 doses of tetanus toxoid or if immunization status is unknown along with a tetanus-prone wound (e.g., obvious soil contamination, >6 hours old) should receive tetanus prophylaxis.

How Do You Manage a Patient Who Presents with Impalement?

Patients who present with an impaled object (e.g., knife, arrow, rebar, etc.) should be assessed in the same manner as other patients with penetrating trauma. No attempt should be made to remove the impaling object until the anatomy of the injury has been identified on imaging studies. These objects are best removed in the operating room under controlled conditions.

Subsequent Management

Why Are Trauma Patients Prepped and Draped From Chin to Knees in the Operating Room?

Trauma patients taken to the OR should be prepped widely to allow for access to all critical areas of the body. Immediate access to the left chest is crucial should a trauma patient lose

vital signs and require a resuscitative thoracotomy to maintain cardiocerebral perfusion. Access to the groins allows for the harvesting of saphenous vein should a vascular conduit be required at the time of initial operation.

What Is the Traditional Mainstay of Surgical Management for Patients with Penetrating Abdominal Trauma?

Exploratory laparotomy is the traditional mainstay of surgical management for patients with penetrating abdominal trauma.

Is There a Role for Laparoscopy Following Penetrating Abdominal Trauma?

Yes, in select patients who do not have an indication for immediate laparotomy (hypotension/shock, peritonitis, evisceration), laparoscopy can be utilized to determine if the penetrating injury has penetrated the peritoneum. If there is no peritoneal penetration, laparotomy is not necessary. If laparoscopy demonstrates that the peritoneum is violated, a laparotomy is generally performed as laparoscopy may miss injuries (such as subtle bowel injuries). The value of laparoscopy is that it reduces the risk of a negative or nontherapeutic laparotomy, which is associated with up to 5% mortality and 20% morbidity rates. In addition, with upper abdominal penetrating injuries, laparoscopy can identify diaphragm injuries (which require repair).

What Is the “Lethal Triad of Death” in Trauma?

The lethal triad of death (■ Fig. 43.1) refers to the three key interrelated factors, which if left uncorrected could lead to death in the trauma patient. More recently, the terms “acute traumatic coagulopathy” or “coagulopathy of trauma” have been employed to describe the multitude of factors resulting in widespread and uncontrollable hemorrhage in severely injured patients.

What Is Damage Control Surgery?

Patients with massive hemorrhage and multiple injuries are at high risk of death once hypothermia, coagulopathy, and acidosis develop intraoperatively. At that point, the surgeon must make the decision to stop surgery (even if every injury is not repaired), transport the patient to the ICU, and correct the lethal triad, with a plan to re-explore the patient after correction of these physiologic derangements. This approach is called *damage control surgery*. It involves limiting surgery to controlling life-threatening hemorrhage and temporarily

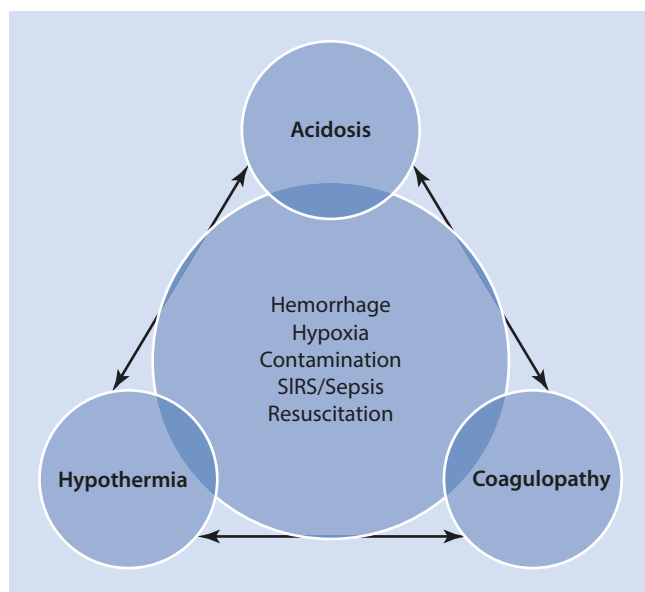


Fig. 43.1 Lethal triad of death in the trauma patient (From Beekley AC. Initial management priorities: beyond ABCDE. In: Martin MJ, Beekley AC, eds. *Front line surgery*. Springer, New York. © Springer Science+Business Media, LLC 2010, Reprinted with permission)

controlling gastrointestinal contamination, followed by temporary closure of the abdomen (typically with a negative-pressure wound vacuum) and transfer to the ICU for ongoing resuscitation. Once patients are adequately resuscitated, they are brought back to the operating room to undergo definitive repair of the injuries.

When Is It Appropriate to Consider Nonoperative Management of Patients with Penetrating Abdominal Trauma?

Nonoperative management of penetrating abdominal wounds may be appropriate in a certain subset of patients. In order to be considered for nonoperative management, four essential criteria must be met (listed below). Selective nonop management is employed to reduce the incidence of nontherapeutic laparotomies and the complications associated with these operations. In general, most patients with penetrating abdominal trauma are managed with an exploratory laparotomy.

Criteria for Nonop Management of Penetrating Abdominal Trauma

- Hemodynamically stable patient
- No peritonitis
- Evaluable (normal mental status)
- CT scan demonstrating no intra-abdominal injury

How Long Should Antibiotics Be Continued for Following a Trauma Laparotomy?

A single dose of antibiotics administered preoperatively is usually adequate, although some physicians may elect to continue antibiotics for up to 24 hours postoperatively. Even in the presence of a colon injury, a longer duration of antibiotics is not associated with a decreased incidence of infections and may predispose to the development of resistant organisms.

Do Patients with Small Bowel or Colon Injuries Require a Stoma?

Rarely do patients with small bowel or colon injuries require a stoma. The majority of both small and large bowel injuries can be repaired primarily or undergo a resection with primary anastomosis.

What Is the Best Management for a Patient with an External Iliac Artery Injury in the Presence of a Contaminated Abdomen Due to a Colon Injury?

As with all vascular injuries, the first steps involve obtaining arterial control proximal and distal to the injury. In the face of contamination with stool, autologous vein graft (such as reverse saphenous vein) is the bypass conduit of choice. Prosthetic grafts should be avoided in this situation. If damage control surgery is needed, a temporary shunt can be placed to bridge the arterial injury with planned repair within 24 hours. Alternatively, the external iliac artery can be ligated and circulation restored to the lower extremity with a femoral artery to femoral artery bypass.

Watch Out

Patients with injuries to the colon and common iliac artery are at an increased risk for injury to the *ureter*.

Complications

What Is Abdominal Compartment Syndrome? Who Is at Risk?

Patients with multiple traumatic injuries, particularly intra-abdominal or retroperitoneal, who have received large volume of fluids and blood products are at risk of developing intra-abdominal hypertension (IAH) which can

progress to abdominal compartment syndrome (ACS). ACS should be suspected in any severely injured patient who demonstrates decreased urine output, increased peak airway pressures on the ventilator, and increased vasopressor support, in the absence of another identifiable cause. Bladder pressures should be measured as a surrogate of intra-abdominal pressure. The treatment is to take the patient to the operating room and perform a decompressive laparotomy by reopening the abdominal fascia and leaving the wound open.

Watch Out

In the case of ACS secondary to ascites, a therapeutic paracentesis can be performed first to decrease IAH. If this does not resolve ACS, decompressive laparotomy needs to be performed.

Special Situations/Circumstances

Thoracoabdominal Penetrating Wounds

Penetrating injuries to this area can present a challenge as there may be concomitant injuries to the thoracic cavity, mediastinum, heart, diaphragm, retroperitoneum, and abdominal cavities. The decision regarding which cavity to enter first (chest or abdomen) is not always apparent.

Summary of Essentials

History and Physical Exam

- GSWs and stab wounds are the most common mechanisms.
- Every effort should be made to identify all wounds.
- Hypotension, peritonitis, and evisceration mandate operation.
- Tangential GSWs may cause blast injury.

Anatomy

- The peritoneal cavity, pelvis, and retroperitoneum comprise the internal abdomen.
- Injuries to retroperitoneal structures are difficult to diagnose.
- Retroperitoneal hematomas; three zones.
- Liver and small bowel are the most commonly injured organs following penetrating abdominal trauma.

Workup

- Immediate operative exploration if either:
 - Hypotensive
 - Peritonitis
 - Evisceration
- FAST more helpful in blunt trauma:
 - Still useful to rule out cardiac tamponade
- Local wound exploration only if:
 - Hemodynamically stable and no peritonitis with anterior abdominal stab wound
- Liberal use of torso CT (chest, abdomen, pelvis) if immediate operative exploration not indicated

Initial Management

- Start with ABCs.
- Initiate massive transfusion protocol in all unstable patients with suspected major blood loss, if available.
- Consider permissive hypotension in patients with penetrating torso trauma.

Subsequent Management

- Damage control surgery.
- Minimize operating time.
 - Control hemorrhage.
 - Temporary control of gastrointestinal injuries.
 - Nonoperative management of penetrating abdominal trauma is the exception rather than the rule.
- Most bowel injuries repaired primarily.

Complications

- ACS is diagnosed by an elevated bladder pressure in conjunction with low urine output and elevated airway pressures.

Suggested Readings

- Nicholas JM, Rix EP, Easley KA, et al. Changing patterns in the management of penetrating abdominal trauma: the more things change, the more they stay the same. *J Trauma*. 2003;55:1095.
- Velmahos GC, Demetriades D, Toutouzas KG, et al. Selective nonoperative management in 1,856 patients with abdominal gunshot wounds: should routine laparotomy still be the standard of care? *Ann Surg*. 2001;234:395.
- Zafar SN, Rushing A, Haut ER, et al. Outcome of selective non-operative management of penetrating abdominal injuries from the North American National Trauma Database. *Br J Surg*. 2012;99(Suppl 1):155.



Pedestrian Struck by Motor Vehicle

Zane W. Ashman, Areg Grigorian, Christian de Virgilio, and Dennis Y. Kim

Case Study

A 30-year-old male is struck by a car while crossing the street. He is brought in by paramedics with a blood pressure of 130/70 mmHg, heart rate of 80/min, and a right knee deformity. He is awake and alert and complaining of severe right knee pain. His airway is intact and breath sounds are equal bilaterally. Abdominal and pelvic exams are unremarkable. There is swelling and

an obvious deformity of his right knee. His right foot is pale and cool, with a 6 s capillary refill, whereas the left foot is pink and warm with <2 s capillary refill. Pulse examination reveals normal 2+ pulses in his left femoral, popliteal, dorsalis pedis (DP), and posterior tibial (PT) arteries. On the right, there is a 2+ femoral pulse. Doppler signals on the left foot are triphasic, whereas on the right they are

monophasic. Due to severe knee pain, neither the right knee nor the popliteal pulse can be examined. The right dorsalis pedis and posterior tibial artery pulses are non-palpable. Sensory and motor function is intact bilaterally. There is no tenderness or deformity in the right thigh or in the tibia or ankle. The right lower extremity ankle-brachial index (ABI) is 0.20, whereas the left is 1.0.

Diagnosis

What Is the Most Likely Diagnosis?

Given the mechanism of injury, deformity of the right knee, pale and cool right foot, and absence of distal pulses, this patient most likely has a right popliteal artery injury secondary to a posterior knee dislocation.

History and Physical Exam

What Are “Hard” and “Soft” Signs of Vascular Injury?

Hard signs are specific, overt physical exam findings that, if present, confirm the suspected injury or disease. In general, if a hard sign of vascular injury is present, the thought is that further imaging is unnecessary and would delay definitive treatment. As such, *immediate* operative intervention is recommended when hard signs are present. Soft signs increase the index of suspicion for a vascular injury but are not sufficient for immediate surgery, and thus their presence on exam should prompt further investigation (■ Table 44.1).

■ Table 44.1 Signs of vascular injury

Hard signs	Soft signs
Arterial/pulsatile bleeding	History of hemorrhage in the field
Persistent hemorrhage with shock	Small, stable, non-pulsatile hematoma
Expanding or pulsatile hematoma	Unexplained hypotension
Palpable thrill	Penetrating wounds in proximity to major vessels
Audible bruit	Associated nerve deficit
Absent pulse	Diminished or unequal pulses

Do All Patients with Hard Signs Need to Go Emergently to the OR?

The hard signs of vascular injury were created at a time when formal transfemoral arteriography, a test that would delay definitive management by several hours, was needed to diagnose arterial injuries. Today CT angiogram (CTA) can be obtained within minutes. As such, patients with a palpable thrill or bruit may have time to undergo imaging to better delineate the injury. Similarly, those with an absent pulse (without evidence of acute limb ischemia) can often undergo CTA as well. Those with arterial bleeding, shock, or expanding hematoma should still go directly to the OR and bypass CTA.

What Are the 6 Ps of Acute Limb Ischemia?

Pain, pallor, paresthesia, paralysis, pulselessness, and poikilothermia

What Is the Implication of an Audible Bruit/Palpable Thrill Near an Artery in Association with Trauma?

These are highly suggestive of a traumatic arteriovenous fistula. This needs to be worked up with CTA.

What Are the Principles of the Physical Examination of an Injured Extremity?

The physical exam should include an assessment of vascular, neurologic, musculoskeletal, and soft tissue integrity of the entire limb, including the joints above and below the site of injury. Comparison of potentially abnormal findings to the contralateral extremity should be done.

Physical Examination of the Injured Extremity

- **Vascular**
 - Peripheral pulses above and below the site of injury along with Doppler signals
 - Perfusion of the skin (warmth, color, and capillary refill)
 - Hard and soft signs of vascular injury
- **Neurologic**
 - Sensation, strength, reflexes
- **Musculoskeletal**
 - Fracture or gross deformity
 - Joint exam (passive and active range of motion, joint instability, effusion)
- **Soft tissue**
 - Intact
 - Degree of contamination

Pathophysiology

What Is the Mechanism of Popliteal Artery Injury?

The popliteal artery is susceptible to traction and transection injuries due to its fixed course across the knee joint. The artery is tethered at both its superior border, as the superficial femoral artery exits the adductor hiatus, and its inferior border at the tendinous arch of the soleus. Along its course, the popliteal artery forms a weak anastomotic network around the knee by giving off paired geniculate branches. Posterior dislocation of the knee stretches the relatively fixed popliteal artery, leading to intimal disruption. The most common presentation of popliteal artery injury is thrombosis with acute distal limb ischemia.

What Are the Classic Orthopedic Fractures/Dislocations that Are Associated with Arterial Injury? (Table 44.2)

Table 44.2

Injury	Artery involved	Features
Shoulder girdle dislocation	Axillary artery	<i>Anterior</i> dislocations are more common and present with axillary nerve or artery injuries; <i>posterior</i> dislocations result from seizures and have an increased risk of axillary nerve injury
Clavicle fracture	Subclavian artery	Patients may have associated pneumothorax and/or hemothorax
Supracondylar humerus fracture	Brachial artery	Occurs more commonly in children; may result in Volkmann's contracture if left untreated
Pelvic fracture	Branches of internal iliac artery (superior gluteal and internal pudendal)	Arterial bleeding in the presence of severe <i>posterior</i> fractures is more likely to be due to an injury to the superior gluteal artery. Severe <i>anterior</i> fractures may result in injury to the internal pudendal artery; both can result in hemorrhagic shock (major source of blood loss)
Hip dislocation	Femoral artery	<i>Posterior</i> dislocations present with an internally rotated and adducted leg with an increased risk of sciatic nerve injury. <i>Anterior</i> dislocations present with externally rotated and abducted legs with an increased risk of femoral artery injury; risk of avascular necrosis if combined with femoral head fracture
Knee dislocation	Popliteal artery	Arterial injuries occur more frequently in patients with <i>posterior</i> dislocation than with anterior
Tibial plateau fracture	Popliteal artery	Arterial injuries occur more frequently in patients with <i>medial</i> injuries and less with lateral

Watch Out

Anterior dislocations are the most common shoulder dislocation and can present with axillary nerve or axillary artery injury. Posterior shoulder dislocations are rare and often result from seizures. They are more likely to cause axillary nerve injury than axillary artery injury.

Why Is It Important to Promptly Reduce a Dislocation?

Dislocations that are left unreduced for a prolonged period are associated with poorer long-term outcomes, including limited functional recovery. In the short term, these injuries are associated with significant pain and discomfort which are improved with reduction. Prompt reduction allows for near-normal range of motion and use. Furthermore, unreduced dislocations associated with arterial injuries increase the risk of osteonecrosis of the involved bone.

Watch Out

Always examine a patient's vascular and neurological status both *before* and *after* performing reduction as it can change postreduction.

What Is a Minimal Vascular Injury?

Minimal vascular or arterial injuries refer to clinically silent injuries that are discovered on radiographic studies such as angiography or ultrasonography. These injuries usually have a benign or self-limited course. They involve small intimal flaps or irregularities.

What Is Suggested by Numbness of the Skin Overlying the Lateral Shoulder After Shoulder Dislocation?

Numbness to the skin overlying the lateral shoulder suggests injury to the axillary nerve. This occurs most commonly with anterior shoulder dislocation but can also occur with posterior shoulder dislocation (excessive abduction and external rotation of the glenohumeral joint). Patients may also have poor function of the deltoid muscle with weakened shoulder abduction.

severe pain, imaging has not yet been obtained to rule out fractures, and manipulating the knee may worsen the arterial injury.

What Noninvasive Bedside Test Provides Objective Evidence of a Vascular Injury? How Is It Performed?

The ankle-brachial index (ABI) is a noninvasive bedside test that provides objective evidence of a vascular injury. It is measured with the patient in a supine position. A hand-held Doppler and a blood pressure (BP) cuff are needed to measure ABI. The BP cuff is inflated, while the Doppler is held on the dorsalis pedis artery. The cuff is inflated until the Doppler signal disappears. The cuff is slowly deflated until the signal returns. The systolic pressure at which the signal returns is recorded. The process is repeated with the posterior tibial and bilateral brachial arteries. The ABI is the ratio of the highest systolic pressure at the ankle *or* foot (of the side in question) over the highest brachial systolic pressure (of right *or* left side). A normal ABI is between 1.0 and 1.2. An ABI of <0.90 is highly sensitive and specific for arterial injury following both blunt and penetrating injuries.

Watch Out

In trauma, the API (arterial-pressure index) is often used instead of the ABI (used for peripheral arterial disease). The API compares the blood pressure in the injured extremity to the non-injured extremity, whereas the ABI compares the ankle pressure to the arm (brachial) pressure.

If the ABI Is Abnormal, What Additional Vascular Imaging Study Is Recommended?

If the ABI is <0.9, additional vascular imaging is recommended. Options include formal contrast arteriography, computed tomography angiography (CTA), and duplex ultrasonography. *CTA is currently the test of choice* due to its availability, rapidity, and noninvasive nature. Formal contrast arteriography requires calling in an interventional radiology team which further delays management and is invasive (requires direct femoral artery puncture).

What Additional Radiologic Imaging Study Is Recommended for a Posterior Knee Dislocation?

Postreduction films should be obtained to assess for the adequacy of reduction and to rule out a periarticular fracture.

Workup

Should the Knee Be Tested for Ligamentous Injury?

No. In the acute setting of a severe knee injury, testing for ligamentous injury should not be done as the patient will be in

In Penetrating Trauma, Should an Angiogram Be Performed If the Bullet/Stab Wound Is Close to an Artery, Even If There Are No Signs of Injury?

No. So-called proximity injuries should raise the level of suspicion for vascular injury, but no further workup is warranted in the patient with a normal ABI.

What Is the Mangled Extremity Severity Score and How Is It Used?

In certain situations, particularly those involving extensive soft tissue or musculoskeletal injury of an extremity, with or without associated neurovascular trauma, the limb is so severely injured that the likelihood of salvaging the limb may be in doubt. The Mangled Extremity Severity Score (MESS) is one of the most commonly used scoring systems to quantify injury severity in patients with severe trauma of the extremities (see below). It is designed to help surgeons decide whether to attempt limb salvage or proceed directly to amputation.

Mangled Extremity Severity Score Components

- Patient age
- Severity of shock
- Mechanism of injury
- Skeletal/soft tissue injury
- Ischemia severity (>6 h)

Management

What Are the First Steps in the Management of This Patient?

Initial management (■ Fig. 44.1) of the trauma patient begins with the primary survey to identify and treat immediately life-threatening conditions. The primary survey involves assessing the *ABCDEs* (*a*irway with C-spine precautions, *b*reathing, *c*irculation with hemorrhage control, *d*isability, and *e*xposure/*e*nvironmental control). Among patients with extremity vascular trauma, aggressive efforts should be directed toward identifying and controlling bleeding. The secondary survey is performed only after completing the primary survey and consists of a detailed head-to-toe examination to identify all wounds and injuries not detected during the primary survey.

Is There a Role for Tourniquets in Patients with Life-Threatening Hemorrhage of an Extremity?

Recent literature and guidelines support the use of tourniquets for exsanguinating extremity trauma. These may be placed in the prehospital/field setting and emergency or operating rooms. Improper placement of tourniquets may result in paradoxical bleeding if the pressure applied to the affected limb does not arrest arterial inflow while occluding venous outflow. The solution to paradoxical bleeding is to increase the tourniquet pressure to obtain arterial occlusion. Early application of tourniquets prior to the onset of shock is associated with improved outcomes. Minimizing tourniquet application time to less than 2 h and using side by side or wide occlusion will help minimize tissue damage.

What Is the Next Step in the Management of a Knee Dislocation?

Immediate reduction of the right knee dislocation is indicated in an ischemic limb. Early orthopedic consultation should be obtained.

What Is the Next Step Following Reduction?

Recheck the neurovascular status. If there is still no pulse, start intravenous heparin (provided there are no contraindications such as ongoing hemorrhage) and prepare for surgery. If pulse returns, check the ABI. If ABI is <0.9, obtain a CTA. If the CTA confirms arterial injury, take the patient to the operating room.

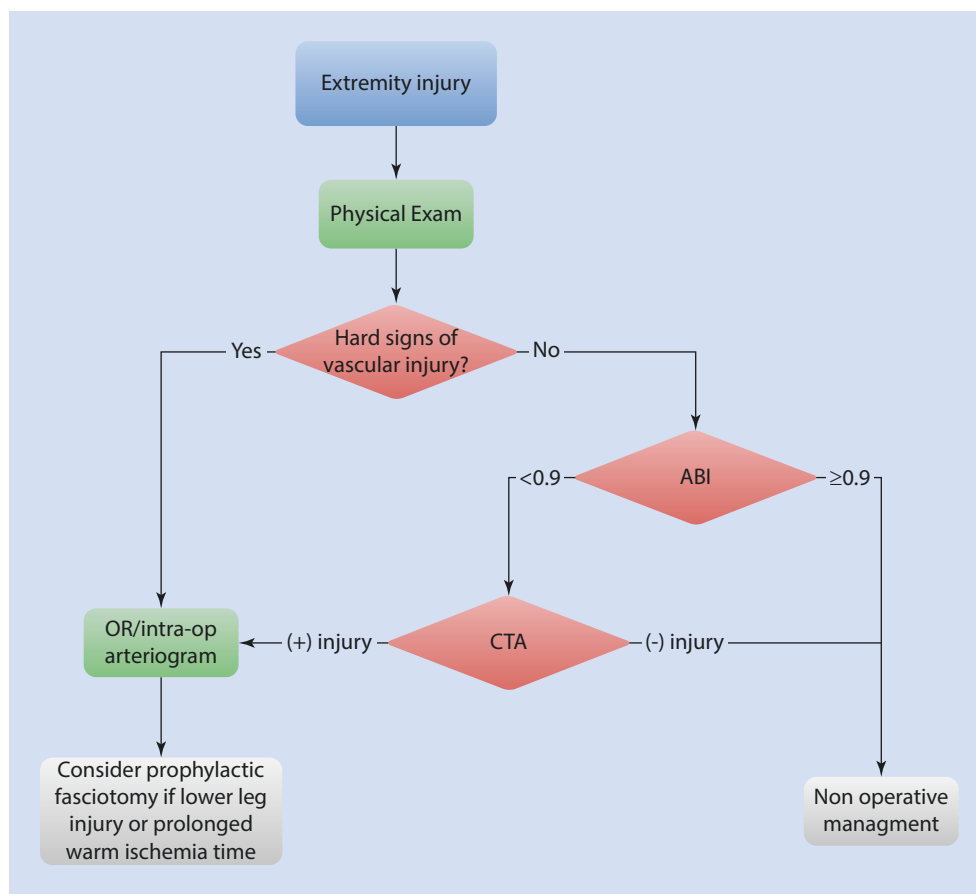
What Are the Principles of Operative Management of a Popliteal Artery Injury in This Setting?

The focus of operative management is restoration of circulation. Definitive management within 6 hours of injury offers the best chance of limb salvage with minimal neurologic deficits in the ischemic limb.

If a Conduit Is Needed to Replace the Injured Artery, Where Is It Taken From?

Autogenous vein grafts offer better long-term patency compared to prosthetic grafts and lower risk of infectious complications following repair in contaminated wounds. The proximal greater saphenous vein is harvested from the

Fig. 44.1 Algorithm for extremity injury management



contralateral, uninjured leg (and must be reversed due to valves). This approach is preferred to preserve collateral venous circulation of the injured leg in the context of a possible popliteal venous injury.

Watch Out

In general, a conduit is chosen from the *contralateral* extremity in trauma patients, while the conduit in a patient with peripheral arterial disease undergoing bypass/repair is chosen from the *ipsilateral* extremity.

What If the Popliteal Vein Is Also Injured?

The vein should be repaired if it can be done easily and if the patient is stable. Otherwise the injured vein can be ligated. The risk of compartment syndrome markedly increases with combined arterial and venous injury. As such, prophylactic four-compartment lower extremity fasciotomies are recommended.

What If There Is a Combined Orthopedic and Vascular Injury, Which Is Repaired First?

This depends on the severity of ischemia to the limb. The issue is as follows: if the bone is fixed first, and the patient has severe arterial ischemia, a prolonged orthopedic procedure may lead to irreversible muscle and nerve ischemia. Alternatively, if the artery is repaired first, and then the orthopedic injury is repaired after, the required manipulation of the bone may disrupt the arterial repair. Thus, if the limb is markedly ischemic, it is recommended to insert a shunt proximal and distal to the injured artery so as to restore flow. This permits a less rushed orthopedic surgery. The artery can then be fixed afterward. If the arterial injury has not caused limb ischemia, the orthopedic injury is fixed first, followed by the arterial repair.

Does Heparin Administration Help?

The benefit of heparin for penetrating arterial trauma is somewhat controversial. However, in the setting of blunt popliteal injury (and in particular with an ischemic limb),

systemic heparin administration is recommended. It is thought to reduce rates of amputation by preventing microvascular thrombosis in the setting of low-flow arterial circulation. Contraindications to heparinization include active hemorrhage, intracranial injury, and coagulopathy.

What Is the Risk of Limb Loss with a Posterior Knee Dislocation and Popliteal Injury?

This injury has a high risk of limb loss, ranging from 30–50%. This is largely due to the poor collateral blood supply around the knee, associated extensive arterial thrombosis, associated venous injury, and risk of postoperative compartment syndrome. Early recognition of compartment syndrome from reperfusion injury is essential.

Area Where You Can Get in Trouble

Assuming There Is No Arterial Injury Because the Patient Has Palpable Pulses

The pulse exam is very unreliable in adequately assessing vascular injury. It is not uncommon for the examiner to feel their own pulse. Thus, always measure the ABI in conjunction with the pulse exam to confirm normal blood flow.

Area of Controversy

The Role of Endovascular Repair

The use of endovascular techniques to repair extremity vascular trauma has increased over the last decade. Good candidates for endovascular repair are those who are hemodynamically stable with a wound location that is difficult to access surgically (proximal limb injuries with extension into the chest or abdomen, so-called junctional injuries). Patients at risk for compartment syndrome or those requiring embolectomy are not good candidates for endovascular repair.

Summary of Essentials

History and Physical Exam

- Always start with the ABCs.
- Suspect popliteal artery injury with posterior knee dislocation.

- Look for hard signs of vascular injury.
- Assess the neurologic and vascular function with any extremity injury.

Diagnosis

- No testing is needed if hard signs are present.
- Expedited operative repair is required.
- ABI testing is sensitive and specific for significant extremity vascular injury.
- CTA if soft signs of injury or abnormal ABI.
- Vascular imaging is not needed with a normal pulse and normal ABI (≥ 0.9).

Management

- Immediately reduce the dislocated joint.
- Reassess neurovascular function after reduction.
- Hard signs of vascular injury are indications for surgery.
- Start heparin in the pulseless extremity with no contraindications to anticoagulation.
- Repair the injured artery with reverse saphenous vein from contralateral leg.

Prognosis

- Mangled Extremity Severity Score.
- Risk of limb loss depends on duration of limb ischemia, patient age, hemodynamic status, severity of neurovascular injury, and severity of soft tissue injury.

Suggested Readings

- Johnson CA. Endovascular management of peripheral vascular trauma. *Semin Intervent Radiol.* 2010;27(1):38–43.
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- Vogel TR, O'Donnell PL, Trauma JGJ, injuries t. Injuries to the peripheral blood vessels. In: Ashley SW, editor. *ACS surgery* [online]. Philadelphia: Decker Intellectual Properties; 2012.



Gunshot Wound to the Left Neck

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Case Study

A 30-year-old male presents to the emergency department with a single gunshot wound (GSW) to the left neck. The patient is hemodynamically stable, with a blood pressure of 120/70 mmHg, heart rate of 100/min, respiratory rate of 16/min, and a Glasgow Coma Scale (GCS) score of 15. He is able to speak and states that his voice sounds normal to him. There is no stridor or odynophagia. He denies any weakness or numbness in his arms or legs. On physical examination, he is awake and alert. There is a single wound in the left mid-neck between the cricoid cartilage and the angle of the mandible with no bleeding. There is a moderate but nonexpanding hematoma overlying the injury with no other wounds seen. There is no palpable crepitus or audible bruit. Neurological examination is normal.

History and Physical Examination

What Are the Most Important Parts of the History and Physical Examination for a Patient with a Neck Injury?

Mechanism of injury (e.g., penetrating vs. blunt), location of injury, and clinical exam findings

What Are Hard Signs of Vascular Injury?

“Hard signs” are physical exam findings that indicate the presence of a significant vascular injury. They include active arterial bleeding, pulsatile or expanding hematoma, or the presence of shock, a palpable thrill, audible bruit, and neurological deficits that indicate a possible stroke. The presence of one of these findings (particularly the first three) is an indication for *immediate* surgical exploration.

What Are Other Nonvascular Hard Signs that May Warrant a Surgical Exploration?

In addition to the vasculature, there are “hard signs” for the aerodigestive system that also prompt most trauma surgeons to consider *immediate* operative exploration. These include massive hemoptysis or hematemesis, bubbling or food particles in the wound, and respiratory distress. More controversial is large quantities of subcutaneous emphysema (suggesting a tracheal injury), though most agree that it should prompt rapid evaluation.

What Is the Significance of the Following Signs/Symptoms? (Table 45.1)

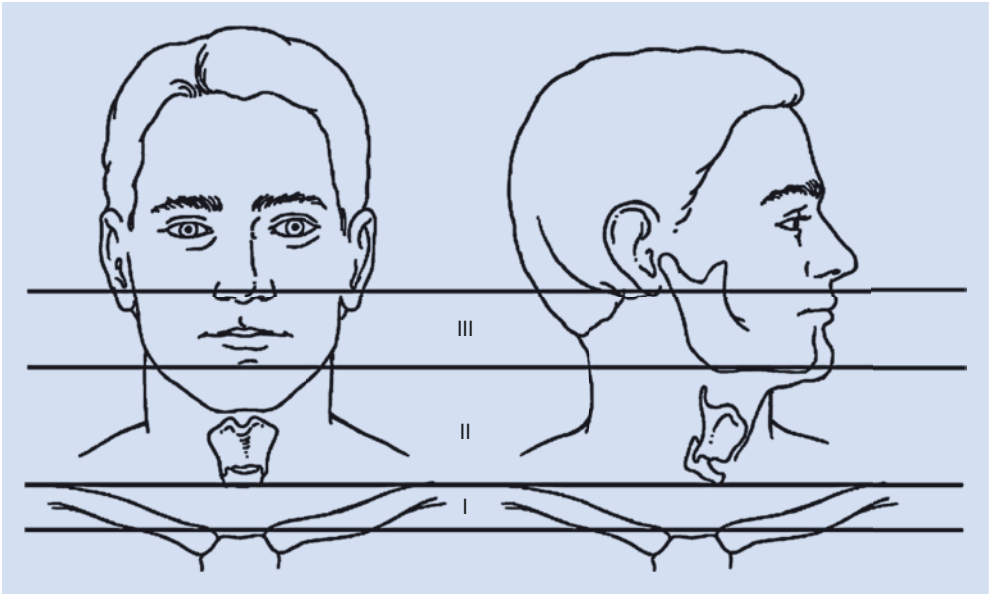
Table 45.1

Sign/symptom	Significance
<i>Stridor</i>	Stridor is a sign of upper airway obstruction caused by compression of the trachea from a large hematoma, soft tissue swelling, direct laryngeal injury, or bilateral recurrent laryngeal nerve injury; it warrants immediate attention to the airway, usually in the form of endotracheal intubation
<i>Odynophagia</i>	Pain with swallowing is suggestive of an injury to the oropharynx or esophagus
<i>Horner's syndrome</i>	The sympathetic fibers that innervate the pupil, eyelid, and skin surrounding the eye travel to these locations along the course of the common carotid and internal carotid arteries; thus, Horner's syndrome (ptosis, miosis, and anhidrosis) may indicate injury to these vessels in the neck on the basis of anatomical proximity
<i>Thrill/bruit</i>	Damage to the subclavian or carotid artery and adjacent vein can create an arteriovenous fistula; turbulent blood flow causes the vein to vibrate, leading to a palpable rumble or a whooshing sound on auscultation
<i>Crepitus</i>	Crepitus is a sign of subcutaneous emphysema (air trapped under the skin) secondary to injury of the aerodigestive tract (trachea, bronchus, or esophagus) or lungs
<i>Hoarse voice</i>	Dysfunction of the vocal cord either because of direct trauma or damage to the vagus or recurrent laryngeal nerve causing ipsilateral vocal cord paralysis

What Is the Diagnosis in This Patient?

The patient has a penetrating neck injury in Zone 2 of the neck (see discussion below), without hard signs of injury. Despite the lack of hard signs, injury to critical structures needs to be ruled out. While evaluating the wound is essential, it is critical not to probe the injury as this could dislodge a clot.

Fig. 45.1 Zones of the neck. (From Harrigan MR, Deveikis JP. Extracranial cerebrovascular occlusive disease. In: Handbook of cerebrovascular disease and neurointerventional technique. Contemporary medical imaging. Humana Press, Totowa; 2009. Reprinted with permission)



Anatomy

What Are the Zones of the Neck and What Are Their Borders?

In the setting of penetrating trauma, the neck is divided into three anatomic zones (■ Fig. 45.1) in order to summarize structures that are at risk for potential injury.

Watch Out

Remember that the neck zones are numbered in the direction of carotid blood flow.

What Key Anatomic Structures Are At Risk of Injury Within the Three Zones of the Neck? (■ Table 45.2)

■ Table 45.2			
Zone	Lower border	Upper border	Anatomic structures within zone
1	Clavicles and sternal notch	Cricoid cartilage	Great vessels, common carotid and vertebral arteries, jugular veins, lung apices, thymus, thoracic duct, distal trachea, esophagus, cervical spine and cord, thyroid gland, brachial plexus, and thoracic duct
2	Cricoid cartilage	Angle of the mandible	Mid-carotid and vertebral arteries, jugular veins, esophagus, vagus nerve, recurrent laryngeal nerve, phrenic nerve, cervical spine and cord, larynx, and trachea
3	Angle of mandible	Base of skull	Proximal internal and external carotid arteries, vertebral arteries, uppermost segments of jugular vein, oropharynx, and cervical spine and cranial nerves 9–12

Watch Out

The three structures located in the carotid sheath include the common carotid artery, internal jugular vein, and vagus nerve.

Pathophysiology**What Is the Significance of Whether or Not the Injury Has Penetrated the Platysma (Superficial Neck Muscle)?**

Injuries that do not penetrate the platysma are non-penetrating neck injuries. As these injuries do not place the vital structures of the neck in harm's way, they do not require any further diagnostic workup or surgical exploration. However, it is often difficult to be confident that the platysma is not violated based on physical exam alone.

What Types of Arterial Injuries Do Bullet Wounds Cause?

A bullet wound may cause a complete transection of the artery, pseudoaneurysm, intimal injury, dissection, or arteriovenous fistula. If a large artery is completely transected, the patient may quickly exsanguinate. Conversely, the ends of the severed artery may retract and vasoconstrict resulting in thrombus formation which may aid with temporary hemostasis (an important reason to avoid massive fluid resuscitation before surgery). Intimal injuries and dissection may predispose to thrombus formation with the potential for vessel occlusion or embolization.

What Is a Pseudoaneurysm? How Does It Differ From a Hematoma?

A pseudoaneurysm develops when an artery sustains a focal full-thickness injury (all three layers) that is temporarily tamponaded by the surrounding soft tissue. This differs from a hematoma, in which there is no active or ongoing hemorrhage from an injured vessel. Blood continues to be pumped into the pseudoaneurysm cavity, creating a pulsatile quality that may be felt on exam as a pulsatile mass on palpation of the overlying skin.

Watch Out

Pseudoaneurysms are inherently unstable and generally require repair. True aneurysms typically develop slowly over years, and not all require repair.

What Is an Arterial Intimal Injury? How Is It Managed? What Is a Dissection?

The concussive or blast effect of a bullet may disrupt the intima of an artery while not damaging the outer arterial layers. If the intimal injury is minor, it can be managed non-operatively. A large intimal injury can cause clot formation, leading to thrombosis and possible embolism. A large intimal injury can also create a false lumen. If blood enters the false lumen, a dissection occurs, which can also lead to occlusion of the artery. Traumatic arterial dissections are generally managed operatively (unless the dissection has reached an inaccessible area such as the intracranial carotid artery).

Watch Out

IV drug users may present with an inflamed pulsatile mass over an area of recent injection due to accidental insertion of needle into an artery. This is an infected pseudoaneurysm, which is a surgical emergency. Do not attempt to incise and drain!

What Nerve Would Be Injured if This Patient Presented with Vocal Cord Paralysis?

The recurrent laryngeal nerves, which supply the vocal cords, are branches of the vagus nerve. They innervate the intrinsic muscles of the larynx except the cricothyroid (innervated by the external branch of the superior laryngeal nerve). Injury to the vagus nerve in the neck (which is prior to the takeoff of the recurrent laryngeal nerve) or damage to the recurrent laryngeal nerve itself leads to ipsilateral vocal cord paralysis. Normally the vocal cords are contracted to keep the airway open; paralysis of one vocal cord causes it to become fixed in a paramedian position and results in a hoarse voice. Bilateral paralysis of the vocal cords may result in complete upper airway obstruction.

Watch Out

Damage to the phrenic nerve (crosses anterior to the anterior scalene in the neck) causes ipsilateral hemidiaphragm paralysis which may be seen on chest X-ray as an elevation of the diaphragm on the affected side.

Table 45.3

Imaging study	Advantages	Disadvantages
CT angiography	Relatively fast, accurate, and readily available in most emergency departments; this is the preferred first-line imaging study	Nontherapeutic; requires injection of iodinated contrast medium
Duplex ultrasonography	Noninvasive, no need for contrast	Operator dependent, Zones 1 and 3 not well visualized, limited visualization in the presence of hematoma or subcutaneous air
Femoral catheter angiography	Diagnostic and can be therapeutic	Invasive; requires interventional radiologist or endovascular surgery support; risk of stroke, femoral artery injury, contrast-induced nephropathy

Workup

What Studies Are Recommended for Patients with Penetrating Neck Trauma?

Injuries to the vessels, aerodigestive tract, and cervical spine need to be ruled out. A CT scan of the neck and chest with oral contrast and IV contrast is indicated (to look for c spine injury as well as oral contrast extravasation from pharynx/esophagus). This CT does not adequately assess for arterial injury. As such, a CT angiogram (CTA) of the neck and chest is also indicated and should be *performed first*. Advantages/disadvantages of the CTA compared to other arterial imaging modalities are discussed below. If an aerodigestive tract injury is suspected on CT, triple endoscopy (laryngoscopy, esophagoscopy, and bronchoscopy) is performed to better assess for laryngeal, esophageal, and bronchial trauma (Table 45.3).

Management

What Are the First Steps in the Management of a Penetrating Neck Wound?

The initial evaluation (Fig. 45.2) of all trauma patients begins with the primary survey. Airway, breathing, and circulation with hemorrhage control assume the highest priority in the initial assessment and management of the trauma patient as derangements in any one of the ABCs may result in significant morbidity and potentially death. The neck includes anatomic structures vital to the ABCs (the upper airway, the lungs, and the major blood vessels of the neck, respectively). A patient who speaks has a patent airway. In a

penetrating neck injury, the airway can quickly become compromised by an expanding hematoma, bloody secretions, or deterioration in mental status, all of which may be indications for endotracheal intubation and urgent operative exploration. A patient's respiratory rate and effort, oxygen saturation, and breath sounds are key factors in assessing breathing. Circulation can be assessed by blood pressure measurements and evaluation for ongoing significant bleeding. The ABCDE of the primary survey is completed by determination of the patient's Glasgow Coma Scale or disability and complete exposure to rule out other injuries.

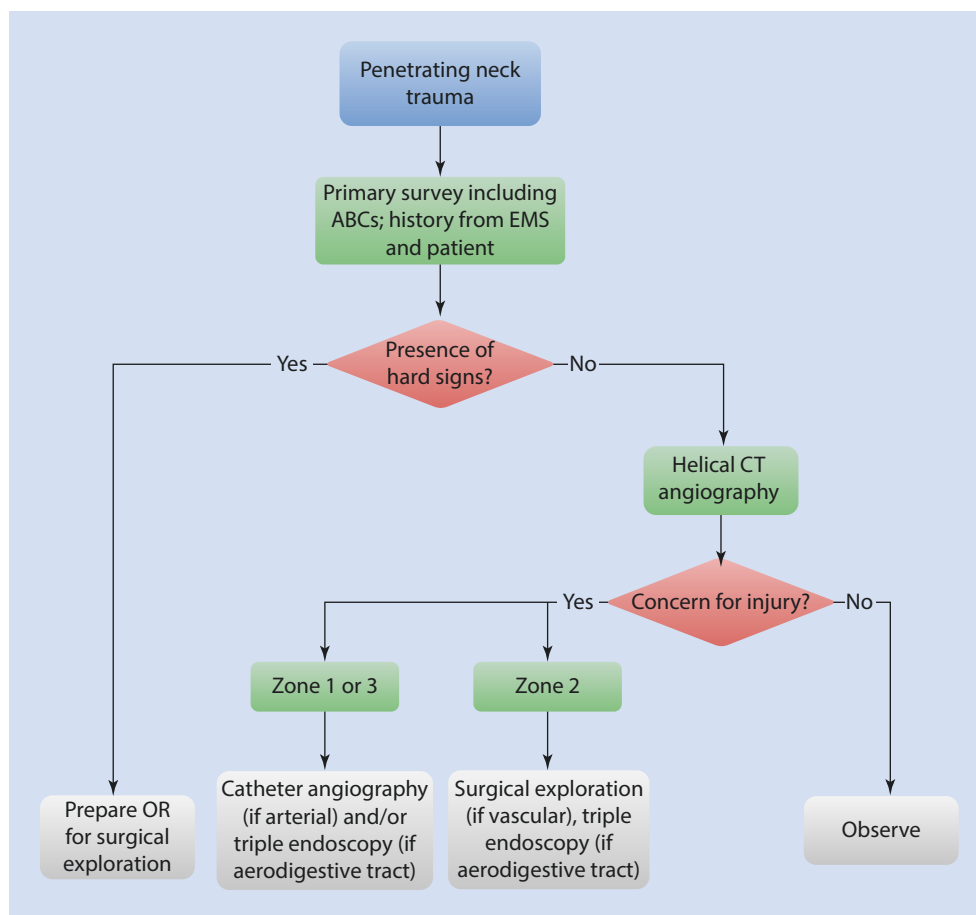
Watch Out

If the patient has an expanding neck hematoma after penetrating trauma, immediately perform endotracheal intubation as the patient may lose their airway from tracheal compression. Do not attempt a surgical airway as you may enter the hematoma.

What Is the Next Step Following the Initial Management?

If hard signs are present (particularly expanding hematoma, hypotension, exsanguination), the patient needs to be taken directly to the operating room. The tenet of repair of arterial injuries is to *first obtain arterial control proximal to the injury and then obtain control distally*, before attempting to enter the injured area. For Zone 2 injuries (most common) that violate the platysma, proximal and distal control can be obtained via a standard incision along the anterior border of the sternocleidomastoid. For Zone 1 injuries, proximal control is a

Fig. 45.2 Management algorithm for penetrating neck trauma



challenge and may require exposure of the aortic arch vessels via either a sternotomy or a thoracotomy. For Zone 3 injuries, distal control is a challenge and may require endovascular techniques to obtain balloon occlusion.

What If There Are No Hard Signs of Injury?

If there are no hard signs, the next step is to obtain a CTA to rule out injuries to the carotid, jugular vein, trachea, pharynx, esophagus, and cervical spine. If the CTA is negative, no surgical intervention is needed. If the CTA demonstrates concern for an injury but is not definitive, then triple endoscopy is recommended (if the concern is for injury to the aerodigestive tract) and/or catheter angiography via femoral artery (if the concern is for an arterial injury). Further management is determined by subsequent findings. If the CTA shows a definitive injury, surgical intervention is recommended (see Fig. 45.2).

How Does the Zone of Injury Affect Management in Patients Without Hard Signs of Injury?

As previously mentioned, Zone 2 injuries are readily accessible via a standard neck incision. As such, when

injuries are suspected, the threshold to explore is lower. Since Zone 1 injuries are harder to expose (need major chest incision) and Zone 3 injuries may be completely inaccessible (at skull base), exploration of these zones should be limited to situations where injuries have definitively been identified.

Watch Out

Patients with penetrating injuries above the clavicles should be evaluated for a pneumothorax.

What Are the Principles of Repair of a Carotid Injury?

After proximal and distal control are obtained, systemic heparin is administered (provided there are no contraindications or concern for bleeding elsewhere). Sections of artery that are bruised or that have intimal injury should be resected. If the ends of the artery can be approximated without tension (usually possible if <2 cm is resected), then a primary anastomosis is performed. Otherwise, a graft (ideally, greater saphenous vein) is interposed between the two ends.

How Do You Manage an Injury to the Internal Jugular Vein?

Ideally, the internal jugular vein is repaired using simple techniques such as a primary repair (termed lateral venorrhaphy) or end-to-end repair. If the jugular vein cannot be simply repaired or the patient is unstable, then ligation of the vein both proximally and distally is an acceptable alternative. This is generally very well tolerated.

How Does the Type of Arterial Injury Seen on CTA Affect Management? (Table 45.4)

Table 45.4	
Injury type	Comments
Pseudoaneurysm	Inherently unstable and thus can rupture and cause massive blood loss in the trauma setting; needs surgical repair
Arteriovenous fistula	Though not unstable, low resistance of vein means it will rarely close, will slowly enlarge over time; needs open surgical repair
Intimal injury	Usually stable, depending on size, may remodel and heal spontaneously; antiplatelets or heparin usually given

Areas Where You Can Get in Trouble

With GSW, Bullets May Cross Zones As well as Sides of the Neck

Determining missile trajectory solely on the basis wounds is not always reliable. Because so much of the management of penetrating neck trauma relies on which zone is violated, it is important to be aware of the possibility of multiple bullet fragments being created inside the neck or bullets ricocheting off bony structures. For this reason, in the stable patient, routine use of CTA is recommended.

Not Addressing Airway First (Even with No Obvious Airway Compromise)

The thick fascial layers surrounding the neck limit the amount of outward displacement of tissue, causing internal compressible structures to become affected even when very little external sign of a hematoma is present.

Missing a Blunt Carotid Injury

Blunt carotid injuries are easily missed as they are often clinically occult (hard signs such as expanding hematoma are

uncommon). Therefore, a high level of suspicion is required to identify these injuries. The classic presentation would be a motor vehicle accident victim with a focal neurological deficit that is not explained by the head CT scan (i.e., no intracranial hematoma). Blunt carotid injury is caused by stretching of the vessel or direct trauma. Common mechanisms of blunt injury include hyperextension injuries of the neck, direct seatbelt trauma, near hanging, cervical spine fractures, and, less commonly, neck torsion from various activities (wrestling or chiropractic manipulation). In such instances, a CTA of the neck should be obtained to rule out injury to the carotid and vertebral arteries. Treatment in most instances is antiplatelet or heparin administration.

Summary of Essentials

History and Physical Examination

- Mechanism of injury, location of injury, and clinical exam findings are the most important parts of the history and physical examination in a patient with penetrating neck trauma.
- Hard signs include arterial bleeding, shock, lateralizing symptoms indicative of a stroke, pulsatile or expanding hematoma, and a thrill/bruit or clear signs of an aerodigestive injury.
- Must assess for injuries to carotid and vertebral arteries, jugular vein, trachea, esophagus, and cervical spine.
- Injuries from blunt trauma can easily be missed as there is usually little outward evidence (i.e., expanding hematoma) of an injury.

Anatomy

- Zone 1, clavicles/sternal notch to cricoid cartilage; Zone 2, cricoid cartilage to angle of mandible; Zone 3, angle of mandible to the base of skull

Pathophysiology

- High-velocity projectiles can cause damage to tissue that is not necessarily in the direct path of the bullet.
- A bullet wound may cause a complete transection of the artery, pseudoaneurysm, intimal injury, or arteriovenous fistula.
- Bilateral paralysis of the vocal cords often leads to complete upper airway obstruction.
- Zone 2 injuries are surgically accessible via a standard neck incision.
- Zone 1 and 3 injuries may be surgically inaccessible through a standard neck incision.
 - If patient is stable, obtain imaging prior to potential intervention with low threshold for endovascular or interventional radiological techniques for hemorrhage control.

Workup

- Patients with penetrating neck injury should be continuously reevaluated for airway compromise from an expanding hematoma with a low threshold for intubation.
- CT angiography is highly specific for carotid/vertebral injury and readily available.
- Duplex US is noninvasive and highly specific but poor at visualizing Zones 1 and 3.

Management

- Start with the ABCs.
- Injuries that do not penetrate the platysma do not require surgical exploration.
- If hard sign (expanding hematoma, active arterial bleed, shock), take directly to the OR for exploration.
- If no hard signs, obtain CT angiogram.
 - If no injury, no further treatment.
 - If suspicion for aerodigestive tract injury, obtain triple endoscopy.
 - If suspicion for vascular injury.

- Zone 2: surgical neck exploration.
- Zones 1 and 3: obtain catheter angiography.
- First principle in operative management of vascular injury: obtain control of normal artery and vein proximal to the injury, followed by exposure and control distal to the injury.
- The maximum amount of artery that can be removed and still allow for primary anastomosis is 2 cm (do not perform primary anastomosis under tension).
- If primary anastomosis is not possible, place interposition graft.
 - Ideal conduit is autogenous graft (greater saphenous vein from the thigh).

Suggested Reading

- Bell RB, Osborn T, Dierks EJ, et al. Management of penetrating neck injuries: a new paradigm for civilian trauma. *J Oral Maxillofac Surg.* 2007;65:691.
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Stab Wound to the Chest

Patrick T. Delaplain, Christian de Virgilio, Areg Grigorian, and Dennis Y. Kim

Case Study

A 20-year-old male is brought in by paramedics after suffering two stab wounds to his chest. In the emergency department, the patient is awake but combative. He responds to questions by stating his name but is flailing his arms and shouting to leave him alone. His breath smells of alcohol. On physical examination, his blood

pressure is 90/70 mmHg, heart rate is 110/min, and respiratory rate is 20/min. His airway is patent. Breath sounds are absent on the left and clear on the right. He has two stab wounds to the left chest, one just above and one just below the nipple. There is no bubbling of air from the wounds. There is palpable crepitus over

the left chest. His neck veins appear to be distended. His trachea is midline. The heart sounds are difficult to hear, but the rate is regular without murmurs. The abdomen is soft and non-tender. The patient is log-rolled and no other injuries are identified.

Diagnosis

What Are Considered the “Lethal” Six Injuries of Thoracic Trauma? (Table 46.1)

Table 46.1

Lethal six	Characteristics
<i>Airway obstruction</i>	Laryngeal trauma, foreign body aspiration, stridor, expanding neck hematoma, and gurgling
<i>Tension pneumothorax</i>	Hemodynamic instability, tracheal shift away from injury, one-way valve in injured lung
<i>Open pneumothorax</i>	Associated with open chest wall injury, air enters pleural cavity through the skin
<i>Massive hemothorax</i>	Lung parenchymal or intercostal artery injury, total whiteout of lung field
<i>Flail chest</i>	Two or more contiguous ribs fractured in two sites leading to paradoxical motion of chest wall, often have underlying lung contusion
<i>Cardiac tamponade</i>	Beck's triad (hypotension, distended neck veins, muffled heart sounds)

Watch Out

The most common cause of airway obstruction occurs in patients with diminished airway reflexes in which a relaxed tongue falls back against the rear of the pharynx.

What Are Considered the “Hidden” Six Injuries of Thoracic Trauma? (Table 46.2)

Table 46.2

Hidden six	Characteristics
<i>Blunt aortic injury</i>	High-energy rapid deceleration injury (e.g., fall from greater than 10 feet, high-speed motor vehicle accident, aviation accident), widened mediastinum, left-sided hemothorax, deviation of the trachea to the right on chest x-ray

Table 46.2 (continued)

Hidden six	Characteristics
<i>Esophageal injury</i>	Penetrating trauma, subcutaneous air
<i>Tracheo-bronchial injury</i>	Massive subcutaneous emphysema
<i>Diaphragmatic rupture</i>	Due to sudden rise in intra-abdominal pressure, the stomach and colon are the most frequently herniated structures; penetrating thoracoabdominal injuries; delayed diagnosis (may be asymptomatic)
<i>Blunt cardiac injury</i>	Ranging from arrhythmias (tachycardia or bundle branch block) to cardiac rupture; associated with sternal fracture and hemopneumothorax
<i>Pulmonary contusion</i>	Develops within first 24 h, often not seen on initial chest x-ray

Watch Out

The “lethal six” and “hidden six” make up the “deadly dozen” of thoracic trauma.

Watch Out

Do not assume that a combative trauma patient's behavior is due to intoxication; it may represent an underlying physiologic derangement such as hypoxia or hemodynamic collapse.

How Is the Diagnosis of Tension Pneumothorax Established?

This is a clinical diagnosis without a need for x-ray confirmation, which will delay treatment. Suspect tension pneumothorax in patients with hypotension, dyspnea, tachypnea, jugular venous distention, unilaterally absent breath sounds, and tracheal deviation away from the injury.

How Is the Diagnosis of Cardiac Tamponade Established?

This is also considered a clinical diagnosis and requires prompt intervention. Patients that present with Beck's triad (hypotension, distended neck veins, and muffled heart sounds) should be suspected of having tamponade. The diagnosis is supported by an immediate bedside FAST (ultrasound) scan demonstrating fluid in the pericardial sac. Patients may also exhibit pulsus paradoxus (decrease in systolic pressure ≥ 10 mmHg with inspiration).

Watch Out

In cases of exam findings suggestive of acute cardiac tamponade (hypotension, distended neck veins, and muffled heart sounds), the chest x-ray will typically be *normal*. A normal cardiac silhouette will often be seen with no other obvious cause for the hypotension (e.g., tension pneumothorax).

What Is the Most Likely Diagnosis in This Patient?

Given that the patient has sustained a penetrating chest injury to the cardiac box in association with Beck's triad, there is a high suspicion for cardiac tamponade. The cardiac box is defined as the area of the anterior chest wall bounded by the sternal notch and clavicles superiorly, the nipples laterally, and the subcostal margin inferiorly. Up to a third of patients with a penetrating wound in this area may have an associated cardiac injury. He also has absent breath sounds on the left. In combination with his hypotension, a tension pneumothorax is also possible.

History and Physical

What Is the Differential Diagnosis for a Combative Trauma Patient?

While alcohol and substance abuse are common in trauma patients, the clinician should be aware that combative behavior (as in the present patient) can be a sign of hypoxia, shock, or hypoglycemia.

What Is the Differential Diagnosis of the Absent Breath Sounds on the Left?

Pneumothorax or massive hemothorax.

What Is the Implication of a Penetrating Injury to the Chest that Is Above Versus Below the Nipple?

The diaphragm is a dome-shaped muscle that peaks at an imaginary line between the nipples. A penetrating injury above the nipple line likely only involves injury to the thoracic structures. However, injuries below the nipple line may result in damage to either thoracic structures, abdominal contents, or the diaphragm itself, thus prompting investigation of all these areas. Penetrating chest injuries below the nipple are considered "thoracoabdominal." Thoracoabdominal stab wounds can potentially involve thoracic structures, abdominal contents, and/or the diaphragm.

Why Is It Important to Know the Type of Weapon Used in a Penetrating Injury?

While the path of stab wounds can normally be traced, ballistic injuries can be unpredictable in their path. This makes it essential to determine the trajectory of a bullet so an injury is not missed. All wounds should be identified. If there is an odd number of wounds, the bullet must be located radiographically. On rare occasions, bullets may enter an artery and embolize.

What Is the Concern Given that the Systolic and Diastolic Pressures in the Patient Presented Are So Close to Each Other?

A pulse pressure (systolic minus diastolic blood pressure) less than 30 mmHg is considered narrow and is indicative of reduced left ventricle stroke volume. In the trauma setting, the differential diagnosis for a narrow pulse pressure is typically reduced preload (e.g., hemorrhagic/hypovolemic shock) or obstructive shock (e.g., pericardial tamponade, tension pneumothorax).

Why Is It Important to Roll the Patient Over?

In all patients with penetrating trauma, it is critical to check for wounds to the back that may otherwise be missed. The axilla and perineum are two other areas that should be examined in patients with penetrating mechanisms of injury. In general, cervical spine immobilization in patients with penetrating injuries is not required given the extremely low incidence of unstable cervical spine fractures.

What Is the Significance of Air Bubbling from a Penetrating Chest Wound?

This is also referred to as a sucking chest wound, a type of open pneumothorax (■ Table 46.3). An open pneumothorax indicates there is an injury to the lung or bronchial tree that

Table 46.3 Types of pneumothorax

Type	Population	Etiology
<i>Primary spontaneous pneumothorax</i>	Young, tall, thin, male, smokers	Spontaneous rupture of apical alveolar blebs
<i>Open</i>	All trauma patients	Free communication between the atmosphere and pleural space through a large chest wound communicating with the pleural space
<i>Simple</i>	All trauma patients	Jagged rib fracture punctures lung; stab or gunshot wound
<i>Tension</i>	All trauma patients	Lung injury or chest wall injury creates one-way valve
<i>Iatrogenic</i>	Patients with central line or thoracentesis	Direct needle injury to the lung

connects directly to the atmosphere. With a sucking chest wound, the chest wall defect is so large (at least 2/3rd the diameter of the trachea) that inspired air takes the path of least resistance and enters the chest cavity through the wound instead of through the trachea.

Watch Out

Always order a chest x-ray after inserting a central line to make sure you did not cause an iatrogenic pneumothorax. Hypotension or shortness of breath after central line placement should be presumed to be a pneumothorax until proven otherwise.

What Is Subcutaneous Emphysema?

The word emphysema is derived from Greek and means trapped air, which in this case is within the subcutaneous tissues. Crepitus refers to the crunchy sensation on palpation of the skin in the presence of subcutaneous air. In the trauma setting, subcutaneous emphysema is caused by a pneumothorax until proven otherwise.

Pathophysiology**Why Is a Tension Pneumothorax Dangerous?**

Tension pneumothorax is considered the most dangerous type of pneumothorax because the injury creates a one-way valve effect. With each inspiration, air leaks out of the lung and into the pleural cavity or is sucked in from the environment. However, the air is unable to leave the pleural space because of the one-way valve effect. This leads to compres-

sion of the vena cava resulting in decreased preload, severe reduction in cardiac output, and eventual hemodynamic collapse.

What Is the Implication of Distended Jugular Veins?

Distended jugular veins are suggestive of elevated jugular venous pressure, an indirect measure of central venous pressure. In the trauma patient, it should raise the suspicion of either cardiac tamponade or tension pneumothorax.

Watch Out

Consider a large hemothorax in a patient with hemorrhagic shock, contralateral tracheal deviation, decreased breath sounds, and dullness to percussion.

What Causes Hypotension in Cardiac Tamponade?

The pericardial sac is a fibrous structure that does not stretch as it fills with fluid, which means that the pressure increases as the volume of fluid increases. Initially, the pressure of the cardiac chambers remains above the pressure in the pericardial sac. However, eventually the pressure in the pericardium begins to equalize with the cardiac filling pressures causing the atria to collapse and the ventricular stroke volume to decrease. Though there are elevated pressures in all chambers of the heart, the transmitted pressure causes the septum to shift in an exaggerated fashion into the left ventricle compromising preload and cardiac output, which in turn causes hypotension. Eventually, the pressure in the pericardial sac will equilibrate with or exceed cardiac filling pressures leading to complete circulatory collapse.

What Is the Most Important Factor in the Development of Cardiac Tamponade?

The rapid accumulation of fluid is the most important factor. If fluid accumulates slowly, the pericardial sac is better able to accommodate by stretching, and volumes of up to 1 liter can potentially be asymptomatic. However, volumes as small as 150 ml in *acute* cardiac tamponade can reduce cardiac output.

Does a Normal Abdominal Examination Rule Out an Intra-abdominal Injury? Why or Why Not?

No. A penetrating injury to the colon or small bowel may not immediately create peritonitis (it may take several hours to manifest). A reliable physical examination also requires a cooperative and reliable patient. Intoxication, a depressed

mental status, and associated “distracting” injuries may all interfere with the accuracy of the abdominal examination. Since the patient described has an injury below the nipple, intra-abdominal injuries need to be ruled out.

Why Are Penetrating Chest Trauma Patients at Increased Risk of Air Embolism? How Would It Present?

Air embolisms can occur in both the venous and arterial systems and are potentially life-threatening. If air were to enter the coronary arteries, blood flow to the heart could be interrupted resulting in myocardial infarction. Concomitant injury to a bronchus and pulmonary vein may result in an air embolism. Stab wounds or gunshot wounds near the hilum are the most common mechanism of such injuries as this is where these two structures lie in close proximity. Symptoms of air embolism can manifest in the cardiovascular (chest pain, arrhythmia, right-sided heart failure), respiratory (dyspnea, hypoxia, hypercarbia), and central nervous (confusion, altered mentation, stroke) systems.

Why Would a Trauma Patient Lose Pulses (Cardiac Arrest) After Induction or Intubation During General Anesthesia?

Trauma patients with significant, life-threatening injuries may be relying on the sympathetic surge occurring after trauma to keep vital organs perfused. Induction agents used in general anesthesia notoriously disrupt this sympathetic surge, and if coupled with decreased preload (e.g., hypovolemia, obstructive shock), this can result in circulatory collapse. In addition to the induction agents used in general anesthesia, after endotracheal intubation the patient is subjected to *positive end-expiratory pressure (PEEP)* which increases intrathoracic pressure. Similarly, in the setting of decreased preload, the initiation of mechanical ventilation with PEEP can also result in a loss of cardiac output and subsequent cardiac arrest.

Watch Out

A tension pneumothorax is rapidly exacerbated by positive-pressure ventilation. Thus, a tension pneumothorax should be decompressed immediately with a needle decompression/aspiration followed by a chest tube as soon as it is suspected.

Initial Management

What Is the First Step in Management?

The management of any trauma patient always starts with the primary survey (ABCDE: airway, breathing, circulation, disability, exposure). The first question one should always ask is whether the patient needs to be intubated. This decision is usually not based on a specific criterion but rather based on the

clinician's best judgment. The above patient is able to talk and his airway is not obstructed; he does not need to be intubated.

Watch Out

Do not intubate and institute positive-pressure ventilation in a patient with suspected cardiac tamponade unless ready to treat the tamponade (prepped and draped in the operating room). Positive-pressure ventilation results in reduced cardiac filling, which can exacerbate the already compromised cardiac output seen in cardiac tamponade.

What Is the Next Step?

The patient has absent breath sounds on the left. In a stable patient, the next step would be to obtain a chest x-ray to rule out a pneumothorax. However, the patient presented is hemodynamically unstable (blood pressure < 100 mmHg, pulse > 100/min). Because there is concern for a tension pneumothorax, a needle decompression (needle thoracostomy) should be performed urgently.

What Is a Needle Thoracostomy? What Is the Indication for Placement? Where Is It Placed? Why Is That Location Chosen? What Needs to Follow After It Is Placed?

Needle thoracostomy allows for immediate thoracic decompression and is indicated in patients with clinical signs and symptoms (as in the present case) consistent with tension pneumothorax. A needle is placed in the 2nd or 3rd intercostal space, just above the rib, at the midclavicular line and is advanced until air is aspirated into the syringe. This is an ideal location as it minimizes risk to the heart or the collapsed lung. An immediate rush of air indicates successful decompression and helps convert a tension pneumothorax into a simple/closed pneumothorax. However, this is a temporary measure and needs to be followed with a chest tube placement (tube thoracostomy).

Watch Out

All patients that receive a needle thoracostomy for tension pneumothorax should undergo tube thoracostomy (chest tube) for definitive management. Though one might argue to go directly to a chest tube, immediate decompression is needed, and ATLS recommends initial decompression followed by chest tube placement as a chest tube may require too much time.

What Is a Tube Thoracostomy? What Is the Indication for Placement? Where Is It Placed?

Tube thoracostomy, or chest tube insertion, involves placing a hollow plastic tube between the 4th or 5th intercostal space

at the midaxillary line into the chest to decompress a hemothorax and/or pneumothorax. If a massive hemothorax is encountered (≥ 1.5 l immediately or ≥ 150 – 200 ml/h over 3 h), immediate transport to the operating room for an exploratory thoracotomy is indicated.

Watch Out

Tube thoracostomy is used to drain blood (hemothorax) or air (pneumothorax) from the pleural space, while a resuscitative thoracotomy is a surgical procedure in which the chest is opened in an emergency setting to perform lifesaving and invasive resuscitation maneuvers including release of tamponade, cross-clamping of the descending thoracic aorta, internal cardiac massage, and hemorrhage control.

What Are the Goals and Guidelines for Resuscitative or Emergency Department Thoracotomy (EDT)?

EDT is performed to resuscitate trauma patients who present with a recent or witnessed traumatic full arrest. The primary goals of resuscitative thoracotomy include hemorrhage control, decompression of cardiac tamponade, cross-clamping of the descending thoracic aorta, facilitation of cardiac massage, prevention of air embolism, and repair of cardiac or pulmonary injuries. ■ Table 46.4 discusses the indications and contraindications for EDT.

What Is the Next Step?

Circulation is next. Palpate the central and peripheral pulses. If radial or femoral pulse is verified and is normal and no external bleeding is noticed, circulation can be considered stable temporarily. Two large-bore (14 or 16 gauge) IV catheters, one in each arm, are placed, and blood is drawn.

■ Table 46.4 Indications and contraindications for EDT

Indications	Contraindications
Penetrating trauma with <15 min of prehospital CPR	Penetrating trauma with CPR > 15 min and no signs of life (e.g., respiratory effort, pupillary response, motor activity)
Blunt trauma with <5 min of prehospital CPR	Blunt trauma with CPR > 5 min and no signs of life or asystole
Persistent severe postinjury hypotension (SBP ≤ 60 mmHg) or patient in extremis	

CPR cardiopulmonary resuscitation, SBP systolic blood pressure

Consider administration of a 1 liter bolus of fluid, either normal saline or Ringer's lactate. If there is any sign of external bleeding, manual pressure should be applied. If there are no central pulses, an immediate decision needs to be made as to whether to perform an EDT. In the case of severe or ongoing blood loss, the patient should be transfused with type O or uncrossed blood.

Watch Out

IV catheters should be placed in an extremity above and opposite the site of truncal injury. The most important laboratory study to send in a trauma patient presenting in extremis is a type and cross.

Following the Primary Survey, What Is the Next Step in the Management?

In this hemodynamically unstable patient, the source of instability needs to be quickly ascertained. A FAST scan should be performed to look for fluid around the pericardium. Fluid around the pericardium, coupled with the patient's hemodynamic instability, is highly suggestive of cardiac tamponade.

Once Cardiac Tamponade Is Highly Suspected, What Is the Next Step?

Increasing a patient's preload via intravenous fluids or blood can temporarily overcome tamponade. However, definitive management requires opening the pericardium (to relieve the pressure) and repairing the underlying cardiac injury. Ideally this is performed via a median sternotomy, but an EDT would be indicated in patients with a non-palpable pulse or loss of vital signs. Pericardiocentesis is generally *not recommended* in trauma patients, particularly if surgical capabilities and resources will allow for rapid transport to the operating room. The patient presented is hemodynamically unstable, and there is strong evidence of cardiac tamponade. Thus, the patient should be taken directly to the operating room for a median sternotomy.

Why Is Pericardiocentesis Not Recommended in the Trauma Setting?

Performing pericardiocentesis in the trauma setting is controversial. It is thought to be unreliable as the needle is ineffective in removing what is essentially clotted blood within the pericardial sac. In certain clinical circumstances (i.e., long transport times, lack of available expertise or operating room availability), pericardiocentesis may be lifesaving and a helpful temporizing intervention prior to definitive repair. In general, pericardiocentesis is more effective in the non-trauma setting as the cause of tamponade is more likely to be nonclotted blood or serous fluid.

What Is the Role of a Subxiphoid Window?

Subxiphoid window is an open surgical diagnostic procedure that is performed in a stable patient in whom cardiac tamponade is suspected but not certain (e.g., ultrasound is unavailable or equivocal). The premise behind the technique is that if no blood is found upon opening the pericardium, a full median sternotomy can be avoided. Whereas if blood is found, a full median sternotomy is performed to adequately drain the pericardium and repair any associated cardiac injury. In the unstable patient, a subxiphoid window is contraindicated, as it will delay adequately decompressing and repairing the source of the tamponade.

Are Vasopressors Recommended in the Management of Traumatic Cardiac Tamponade?

No. Most pressors will increase systemic vascular resistance (afterload) which will exacerbate myocardial dysfunction in the setting of traumatic pericardial tamponade.

Subsequent Management

What Should Be Immediately Ordered in All Patients that Present with Combative Behavior?

A rapid serum glucose measurement (e.g., finger-stick glucose), pulse oximetry, and a complete set of vital signs should be obtained in all such patients. Be careful not to quickly attribute combative behavior to alcohol or drug intoxication.

How Much Pleural Fluid Can the Diaphragm “Hide” in an Upright Chest Radiograph?

Up to 500 ml of pleural fluid can be hidden by overshadow of the diaphragm.

What Is the Classic Description for Cardiac Tamponade on Chest Radiograph?

The “water bottle sign” is classically described for diagnosing cardiac tamponade on chest radiography, where the heart has an enlarged and elongated silhouette. However, chest x-ray in acute tamponade is *typically normal*.

How Does a Chest Tube Drainage System Work, and How Do You Look for a Leak?

Chest tube drainage devices are composed of three chambers (Table 46.5). One can look for leaks by checking the water

Table 46.5 Chambers of chest tube draining system

Chamber	Purpose	Connects
Collection	Collects fluid, blood, and pus and measures the volume	Water seal chamber to chest tube
Water seal	One-way valve allows air to be removed from the pleural space but does not allow air to enter the pleural cavity	Suction control chamber to the collection chamber
Suction control	Controls the amount of suction	Wall suction and the water seal chamber

seal chamber. Large leaks will be obvious and are evidenced by bubbles passing through the water seal fluid. If one suspects a small leak but no air bubbles are present, remove the suction, ask the patient to cough, and look for the air bubbles.

How Does Inspiring 100% O₂ Help to Resolve a Pneumothorax?

Breathing 100% oxygen instead of room air (which is 21% oxygen) causes the alveolar partial pressure of nitrogen to fall which gradually washes out nitrogen from tissue and increases oxygen uptake into the vascular system. The subsequent increased pressure gradient between alveolar capillaries and the pneumothorax space results in an accelerated rate of absorption from the pleural space. However administering 100% oxygen is not practical, as the rate of pneumothorax resolution is still slow and oxygen toxicity can ensue.

How Is a Sucking Chest Wound Managed?

Prehospital treatment of a sucking chest wound involves covering the chest wall defect with an occlusive dressing that is taped on three sides. This prevents air from entering the pleural space on inspiration while allowing air to escape during expiration, thereby resulting in reexpansion of the lung while minimizing the risk of developing a tension pneumothorax. In the emergency department, an occlusive dressing followed by tube thoracostomy is recommended.

How Is Flail Chest Managed?

Analgesics should be given to control pain and prevent splinting, which may result in atelectasis, decreased functional reserve capacity (FRC), and hypoxia. Consideration should be given to placement of a thoracic epidural catheter. If oxygenation or ventilation is compromised, patients may require intubation. Other routes of analgesia include paravertebral and intercostal blocks.

What Is the Most Important Management in Patients with Rib Fractures?

Pain control is the most important management in these patients as it helps prevent poor inspiratory effort, hypoventilation, atelectasis, and pneumonia. Epidural thoracic catheters for pain control can help reduce morbidity and mortality, particularly in elderly patients.

When Should Patients Undergo Rib Fixation?

The exact role of rib fixation remains to be fully elucidated. However, current data supports the use of operative fixation in flail segments, particularly if patients are failing standard analgesic therapy or require intubation. The use in non-flail segments remains controversial.

How Would You Manage a Traumatic Air Embolus?

Echocardiogram can be diagnostic for air embolus. However, treatment should not be delayed in patients suspected of having an air embolism. When recognized, patients should be placed in Trendelenburg position with the left side down (Durant's maneuver) and air aspirated from a central venous catheter. This positioning allows the air embolus to move into the apex of the right ventricle.

What Can Increase the Risk of Developing an Air Embolism in a Patient Arriving with Penetrating Chest Trauma?

Patients that are intubated with high positive-pressure ventilation can develop air emboli if a concurrent bronchial and pulmonary vein injury is present. The high pressures favor movement of air from the bronchus into the pulmonary vein and eventually into the left atrium and the systemic arterial circulation.

What Are the Classic Mechanisms and Imaging Findings for Aortic Injury?

Patients with complete aortic transection die in the field. Those with a partial transection or contained rupture may make it to the hospital alive. The classic mechanisms involve an acceleration-deceleration injury, most commonly a fall greater than 10 feet or a high-speed motor vehicle accident. The classic chest x-ray findings are a wide mediastinum with or without a left-sided hemothorax. The most common location for blunt aortic injury is just distal to the origin of the left subclavian artery as the aorta is tethered here by the ligamentum arteriosum.

Complications

What Is the Most Dangerous Complication Following Pericardiocentesis?

Laceration of a coronary vessel is the most dangerous complication of pericardiocentesis and can lead to worsening of cardiac tamponade.

What Nerve Is at Risk When Opening the Pericardium during EDT?

Left phrenic nerve innervating the diaphragm. It passes longitudinally over the posterior aspect of the pericardium of the left ventricle.

How Is a Recurrent or Persistent Hemothorax Managed if Chest Tube Drainage Fails?

A thoracotomy is performed if the hemothorax is > 1500 cc or massive enough to cause hemodynamic instability. In a stable patient, with a smaller hemothorax that isn't adequately drained by a chest tube, a video-assisted thoracoscopic surgery (VATS) procedure is recommended. Leaving a hemothorax undrained is not recommended, as the lung will not completely re-expand (trapped lung or fibrothorax) and creates a risk of empyema (infected hemothorax), and VATS has been shown to be superior to attempting a second chest tube.

What Should You Consider in Patients with a Pneumothorax that Continue to Have a Large Air Leak Following Chest Tube Placement?

Make sure the chest tube is in the proper location and that there are no mechanical obstructions (e.g., kinking, clot in tube) or leaks in the system. If the chest tube is properly inserted and functioning, the most likely etiology of a persistent air leak is a major airway injury such as disruption of the tracheobronchial tree. Patients with such injuries typically also have subcutaneous emphysema on exam and pneumomediastinum on imaging. Unstable patients require immediate intubation. Diagnosis is confirmed with bronchoscopy and repair entails a thoracotomy.

Areas Where You Can Get in Trouble

Long-Term Consequence of Missing a Diaphragm Injury

A diaphragmatic injury sustained on the right rarely has clinical significance. The liver usually prevents herniation of

bowel into the chest. On the left side, the positive intra-abdominal pressure coupled with the absence of a significant barrier (e.g., liver) results in the migration of abdominal viscera into the thoracic cavity (diaphragmatic hernia). In patients with penetrating wounds to the left thoracoabdominal region, a diaphragm injury can only be reliably ruled out with a diagnostic laparoscopy. CT scan is not an adequate study to rule out an acute diaphragm injury after penetrating trauma. If not recognized acutely, the diaphragmatic defect enlarges and may present years later with incarcerated bowel in the chest. The classic presentation is chest pain and shortness of breath in a patient with a remote history of trauma. A chest x-ray will demonstrate bowel gas and air-fluid levels in the left chest. CT scan is needed at that time to confirm the diagnosis. Surgical repair is needed and can be done through the abdomen or the chest, using a minimally invasive or open approach.

Watch Out

A classic chest x-ray finding in a patient with diaphragm rupture is curling of the nasogastric tube in the thoracic cavity.

Do All Patients with Pneumothorax Require a Chest Tube?

No. In cases where patients have a small pneumothorax (e.g., small apical pneumothorax on chest x-ray) or an occult pneumothorax (one that is only seen on CT scan and not on chest x-ray), it can be treated with observation, supplemental oxygen, and repeat chest x-ray. If the patient becomes hemodynamically unstable or develops respiratory distress, needle decompression followed by a chest tube is indicated.

Areas of Controversy

How Accurate Is Focused Assessment with Sonography for Trauma (FAST) in the Setting of Penetrating Trauma?

Most of the trauma literature has focused on the role of FAST in blunt trauma. The utility of FAST in penetrating trauma is limited except for diagnosing cardiac tamponade and pneumothorax. Its greatest value is evidenced by the fact that it helps the clinician concentrate his/her efforts on cardiac, thoracic, or intraperitoneal injuries within minutes of the patient's presentation.

Should Prophylactic Antibiotics Be Given for Chest Tube Placement?

There is currently insufficient evidence to support the routine use of prophylactic antibiotics for these patients.

Special Situations/Circumstances

Following Chest Tube Placement for a Traumatic Pneumothorax/Hemothorax, When Is It Appropriate to Remove It? What Is the Main Risk During Removal?

To minimize the risk of infection, chest tubes should be removed as soon as it is safe to do so. Removing the chest tube is appropriate when there are no air leaks present and the lung is fully expanded, as evidenced on a chest radiograph. The main risk during the chest tube removal is air being inadvertently reintroduced into the pleural cavity, resulting in recurrent pneumothorax. Therefore, it is recommended to remove the chest tube either at the end of expiration or at peak inspiration and to immediately cover the wound with an occlusive dressing.

Initially Stable Patient with Multiple Rib Fractures Has Increasing Oxygen Requirements and Respiratory Distress

Patients with multiple rib fractures can have a flail chest and/or underlying pulmonary contusion, which is not always apparent on the initial chest x-ray and can “blossom” over the first few days. Pulmonary contusions can present with hypoxia, tachycardia, and shortness of breath. A chest x-ray will oftentimes demonstrate opacity over the lung parenchyma (alveolar infiltrate) under the rib fracture. An arterial blood gas should be obtained, and, if indicated, early intubation should be considered.

Summary of Essentials

History and Physical

- Cardiac tamponade and tension pneumothorax are clinical diagnoses.
- Penetrating injury above nipple line likely only involves thoracic structures while below the nipple line can involve thoracic structures, abdominal structures, or the diaphragm.
- Narrowed pulse pressure implies compromised stroke volume.

Differential Diagnosis

- Deadly dozen of thoracic trauma
 - Lethal six: airway obstruction, tension pneumothorax, open pneumothorax, massive hemothorax, flail chest, and cardiac tamponade
 - Hidden six: blunt aortic injury, esophageal injury, tracheobronchial injury, diaphragmatic rupture, blunt cardiac injury, and pulmonary contusion

Pathology/Pathophysiology

- Tension pneumothorax can compress SVC/IVC and result in decreased CO.
- Pericardial pressure exceeds ventricular filling pressure in cardiac tamponade resulting in hypotension.
- The most important factor in cardiac tamponade is the rapid accumulation of fluid.
- The underlying mechanism in air embolism is the traumatic creation of a fistula between an injured bronchus and pulmonary vein.

Management

- Always start with primary survey: airway, breathing, circulation, disability, and exposure.
 - Follow with FAST to look for fluid around the pericardium in patient suspected of having cardiac tamponade.
- All combative patients in ER should get rapid serum glucose, pulse oximetry, and set of vitals.
- Tension pneumothorax is initially treated with needle thoracostomy placed in the second or third intercostal space at the midclavicular line.
 - Always follow this with chest tube.
- EDT indications include:
 - Penetrating trauma with <15 min of prehospital CPR
 - Blunt trauma with <5 min of prehospital CPR
 - Persistent severe postinjury hypotension (SBP \leq 60 mmHg) due to cardiac tamponade, air embolism, or hemorrhage (intrathoracic, intra-abdominal, extremity, or cervical)
- Traumatic cardiac tamponade is treated with median sternotomy.
 - Subxiphoid window can be considered when the diagnosis is uncertain.

- Sucking chest wound is treated with occlusive dressing and chest tube.
- Flail chest and respiratory compromise are treated with analgesics and intubation/mechanical ventilation.

Complications

- Laceration of a coronary vessel is the most dangerous complication of pericardiocentesis.
- Persistent hemothorax is managed with repeat chest tube, VATS, or thoracotomy.

Watch Out

- Always order a chest x-ray after putting in a central line.
 - Intubation and positive-pressure ventilation in tension pneumothorax or cardiac tamponade can reduce cardiac filling leading to circulatory collapse.

Suggested Reading

- ACS-COT Subcommittee on Outcomes Practice management guidelines for emergency department thoracotomy. *JACS*. 2001;193:303.
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Burns to the Face, Trunk, and Extremities

Victor C. Joe, Areg Grigorian, Christian de Virgilio, and Dennis Y. Kim

Case Study

A 25-year-old man arrives to the emergency department an hour after sustaining burn injuries in a house fire. He weighs 70 kilograms. He is awake but appears confused and disoriented. He complains of a severe headache and sounds stridorous. At initial exam, his temperature is 38.3 °C, blood pressure is

90/74 mmHg, heart rate is 120/min, respiratory rate is 26/min, and oxygen saturation is 89%. He has blistering, painful burns to the entire face with singed nasal hairs and carbonaceous sputum. He has burns on his entire chest, abdomen, and back which are painless, circumferential, white, dry, and

leathery. The bilateral upper extremities are also burned with painful, swollen, mottled areas with blisters that appear to have open weeping surfaces. The remainder of his skin that is not burned has a cherry-red appearance. He also has sunken eyes, a dry tongue, and slow capillary refill.

Diagnosis

What Is the Diagnosis and Resulting or Associated Complications Affecting This Patient?

The patient has sustained major burn injuries (i.e., >20% total body surface area) involving the face, trunk, and extremities. He has second-degree burns to the face and bilateral upper extremities and third-degree burns to the chest, abdomen, and back. Singed nasal hairs and exposure to fire in an enclosed space are risk factors for smoke inhalation injury. The presence of carbonaceous sputum coupled with his low oxygen saturation is a hard sign of inhalation injury and should be addressed immediately by securing the airway via intubation and administration of 100% O₂. The cherry-red appearance of his skin along with his confusion and disorientation is concerning for carbon monoxide poisoning. Additionally, he is in hypovolemic shock secondary to the massive loss of fluid as a result of his burn injuries (burn shock).

History and Physical

What Are the Different Levels of Burn Injury and How Do They Present?

Table 47.1

Degree	Involves	Presentation
1st (superficial)	Epidermis only	Similar to sunburn; localized, painful, dry, blanching redness with no blisters
2nd (superficial partial thickness)	Epidermis and part of the dermis (papillary)	Very painful, swollen, warm, pink, moist, blanching with blisters
2nd (deep partial thickness)	Epidermis and part of the dermis (papillary and reticular)	Painful, paler with little to no blanching; may have mottled areas that appear to have open weeping surfaces (hemorrhagic)

Degree	Involves	Presentation
3rd (full thickness)	All of the skin (epidermis and dermis)	Painless and insensate, white/brown/black, dry, leathery, and do not blanch with pressure
4th	All of the skin and underlying bone, tendon, adipose, or muscle	Similar to third degree as deep injury may not be obvious on the surface; however, some may be extensive and disfiguring

Watch Out

The presence of pain is an easy way to differentiate superficial partial-thickness burns (presents with pain) from full-thickness burns (decreased sensation) due to destruction of nerve endings.

What Are the Risk Factors for Burn Injuries?

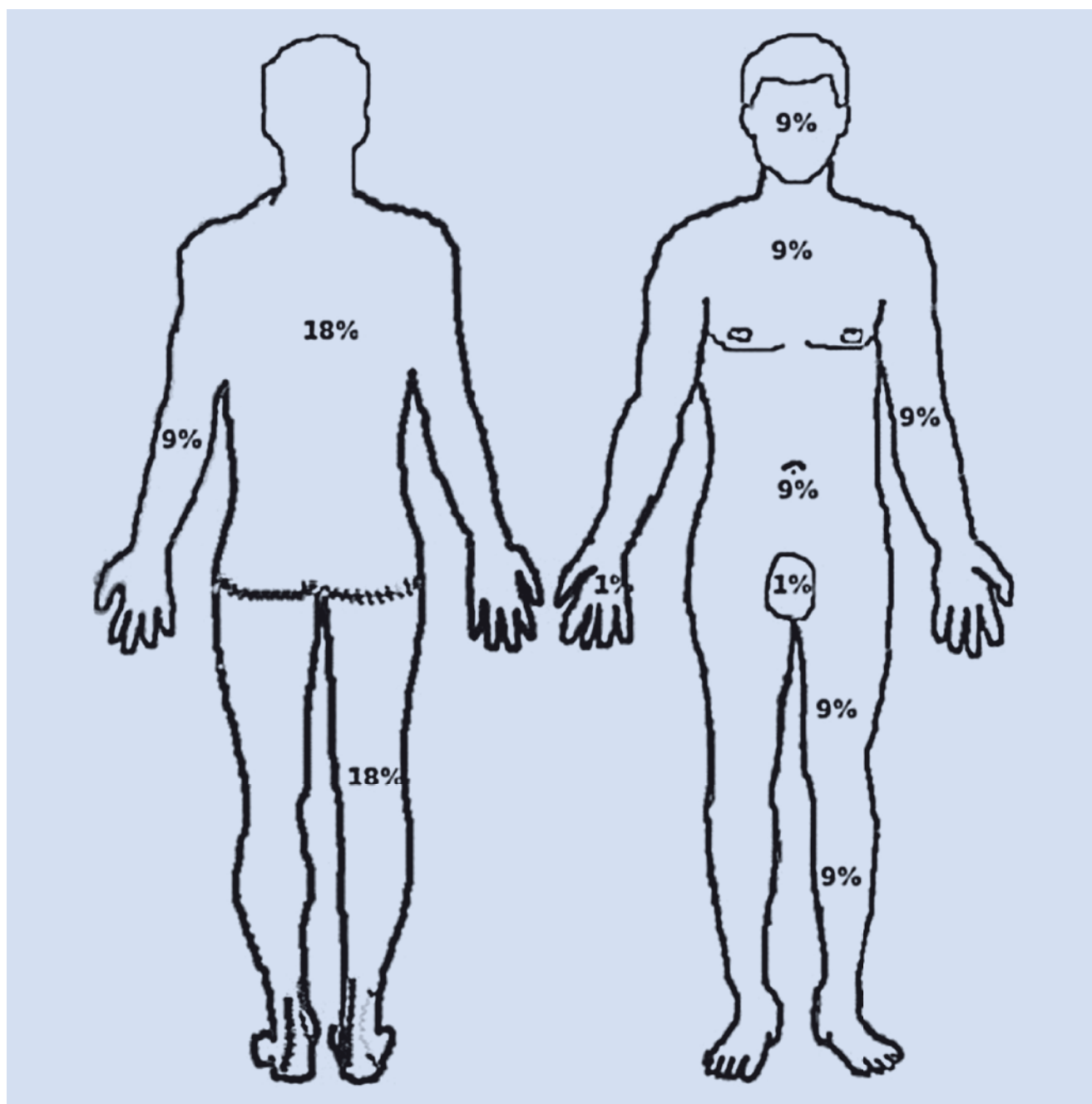
Extremes of age (very young or old), alcohol or substance abuse, smoking, violence, and low socioeconomic status.

How Does One Determine the Severity of a Burn Injury?

Calculating the total body surface area (TBSA) affected by second- or third-degree burns will allow one to determine the severity of a patient's burn injuries. This can be approximated using the rule of nines (■ Fig. 47.1). The body is divided into regions whose surface areas are multiples of nine: head, 9%; each arm, 9%; anterior torso, 18%; posterior torso, 18%; each leg, 18%.

Watch Out

In areas of patchy involvement, the clinician can use the size of the palmar surface of the *patient* (including fingers) to estimate the surface area of the burn. The adult palmar surface area represents ~ 1% body surface area.



■ Fig. 47.1 Rule of 9s in adults

What Are the Criteria for Transferring the Patient to a Burn Center?

- Second- or third-degree burns >10% TBSA in patients <10 or >50 years of age
- Second- and third-degree burns >20% TBSA in all patients
- Second- and third-degree burns involving the hands, face, feet, genitalia, perineum, or skin overlying major joints
- Electrical and chemical burns
- Concomitant inhalational injury
- Significant preexisting medical conditions
- Suspected child abuse or neglect

What Is the Significance of Carbonaceous Sputum?

Carbonaceous sputum indicates possible inhalational injury. There should be a high index of suspicion for patients suffering burn injuries within enclosed areas and with singed nasal hairs or significant facial burns. Changes in voice quality, stridor, and carbonaceous sputum are hard signs of injury. There are three components of inhalational injury: supraglottic (upper airway inflammation/edema), infraglottic (e.g., acute respiratory failure secondary to a chemical pneumonitis from the products of combustion), and carbon monoxide poisoning (i.e., systemic toxicity for gases). As supraglottic edema develops, the patient may lose their airway.

What Is the Significance of Cherry-Red Skin in a Patient Rescued From a House Fire?

This is a classic sign for carbon monoxide (CO) poisoning and typically occurs in patients with prolonged exposure to smoke (e.g., house fires or the exhaust from a running car or gas heater). Patients initially present with headaches and other nonspecific constitutional symptoms such as nausea (carboxyhemoglobin level 10–20%) and dizziness (>20%). If severe or left untreated, CO poisoning may progress to seizures, coma, multiorgan failure, and death.

Can a Second-Degree Burn Progress to a Third-Degree Burn?

Yes. Burn wounds may progress from partial thickness to full thickness due to the natural history of injury (hot oil burns are a common example). Progression may also represent burn wound conversion due to improper wound care or wound complications. One such complication is burn wound sepsis. Signs of infection include a discolored burn, eschar (dry, dead skin) with green pigment, black necrotic skin with skin separation (suppuration), and systemic signs of sepsis. Fever is not always reliable since the body's primary temperature regulator, the skin, is often compromised in burn victims (discussed in *Pathophysiology*). The diagnosis of burn wound sepsis is based upon the bacterial concentration per gram of tissue in the burn wound or eschar. The finding of $>10^5$ bacteria/g of tissue on quantitative analysis is highly suggestive of burn wound sepsis.

What Is the Significance of a Circumferential Burn in the Extremity? How About if on the Chest?

Circumferential full-thickness burns in the extremity significantly increase the risk of developing compartment syndrome. Burn patients with circumferential extremity

full-thickness burns with evidence of compromised distal perfusion should undergo escharotomy. Circumferential burns of the chest can compromise a patient's respiratory efforts due to the inflexible eschar and underlying tissue edema which can prevent chest wall motion and, thus, limit ventilation. These patients should also be considered for chest escharotomy (discussed in *Management*).

What Population of Patients Has the Highest Morbidity From Burn Injuries?

The elderly

What Are the Greatest Risk Factors Associated with Increased Mortality in Burn Patients?

Age >60 years, burns >40% TBSA, and inhalational injury.

Pathophysiology

What Are the Different Causes of Burns?

Table 47.2

Cause	Comments
<i>Thermal</i>	May be from flame, contact with a hot surface, or hot liquid; the most common cause of burn injuries is fire/flame. In children, the most common cause is scalding, typically from hot water
<i>Chemical</i>	Alkali burns are more damaging than acidic burns owing to their ability to penetrate tissues more deeply. Acid burns cause <i>coagulation necrosis</i> , whereas alkali burns cause <i>liquefactive necrosis</i>
<i>Electrical</i>	Immediate life-threatening complication is cardiac arrhythmia. Injuries are often out of proportion to the size of the external burn wound. Patients may also sustain other systemic injuries organs such as muscle necrosis, posterior shoulder dislocations, long bone fractures, and acute kidney injury (myoglobinuria due to rhabdomyolysis)

Watch Out

Direct current (DC) electrocution (e.g., lightning) puts patients at risk for asystole, while alternating current (AC) electrocution (e.g., wall socket) puts patients at risk for ventricular fibrillation.

Watch Out

Cataracts are a long-term complication of electrical injury. There are also neurologic and psychologic sequelae of electrical injury, even at low voltage (<1000 V).

What Are the Physiologic Manifestations of a Burn in the First 24 h?

Severe burn injuries result in the release of numerous inflammatory mediators and a significant systemic inflammatory response. Cardiac output is decreased to 40–60% of normal as a result of decreased plasma volume and increased systemic vascular resistance as well as direct myocardial depression. Cardiac output then returns to normal over the ensuing 24 h. The decrease in plasma volume, which occurs in part from a capillary leak, subsequently leads to hypovolemia and a decrease in central venous pressure. The capillary leak also results in sequestration of proteins in the interstitial space. Together, this leads to edema in both burned *and* non-burned tissue. Due to the release of catecholamines, the circulating glucose concentration is increased during the first 24 h following thermal burn injury (stress hyperglycemia). Proper burn resuscitation is of paramount importance to mitigate the pathophysiologic changes that occur due to major burn injuries.

Why Are Burn Patients at Increased Risk for Severe Volume Depletion?

The skin acts as a protective barrier and plays an essential role in fluid and temperature regulation of the body. When the integrity of this protective layer is compromised, the skin becomes unable to regulate body temperature or prevent fluid from seeping out of the body. This can lead to hypovolemic shock if enough intravascular volume is lost.

Why Are Burn Patients at Higher Risk for Gastrointestinal Ulcers?

Diminished intravascular volume leads to decreased perfusion of the gastrointestinal tract and subsequent mucosal ischemia. In the stomach, this leads to mucosal atrophy and impaired barrier function to acid, thus increasing the risk for ulcer formation in the stomach and duodenum. This is known as a Curling's ulcer.

What Organisms Are Classically Involved in Burn Wound Infections?

Pseudomonas aeruginosa is a gram-negative bacillus and is considered to be the most common cause of infections in burn patients. *Streptococcus pyogenes* was the most common

pathogen in the pre-antibiotic era. *Staphylococcus aureus* predominated thereafter and continues to be a significant source of infection in the early post-burn period. Fungal infections tend to occur in burn patients during the later stages of recovery as patients become more immunocompromised and the majority of bacteria have been eliminated by the use of topical antibiotics. The most common cause of fungal infection is *Candida albicans*. The most common cause of viral infection is herpes-simplex-virus (HSV). As with other hospitalized patients, resistant microorganisms such as methicillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant *enterococci* (VRE) are emerging pathogens. Infections in burn patients can be problematic for multiple reasons. They may delay wound healing and encourage scarring, lead to burn wound conversion, and can result in burn wound sepsis with resultant bacteremia.

Watch Out

In the first several days after the initial burn, the most likely organism in a burn wound infection is a gram-positive organism. Burn wound infections occurring 5 or more days from the initial injury are more likely to be infected with gram-negative organisms and fungi.

Workup

What Is the First Step in the Evaluation of This Patient?

As with any other trauma patient, one should begin with the ABCs and perform a full history/physical examination. It is important to maintain cervical spine precautions and evaluate for concomitant traumatic injuries if the mechanism of injury warrants it. In this patient with hard signs of inhalational injury (stridor, carbonaceous sputum, and hypoxia), securing the airway via endotracheal intubation is essential. Intravenous lines for fluid resuscitation may be placed through burned skin initially if needed.

How Is Inhalational Injury Definitively Diagnosed?

In the absence of stridor and hypoxia, fiberoptic bronchoscopy remains a standard component of the assessment for inhalation injury. However, there is controversy as to whether it predicts the severity of injury clinically, as only the proximal airway can be evaluated. Inhalational injury is suspected in the setting of facial burns, singed nasal hairs, and history of injury in an enclosed space. Other diagnostic features include carboxyhemoglobin >10% and oxygen saturation <90%. Chest X-rays are usually negative initially and have little value in diagnosing inhalational injury.

What Is the Best Way to Evaluate for CO Poisoning?

CO has nearly 200× more affinity for hemoglobin than oxygen. Thus, the hemoglobin-oxygen dissociation curve shifts to the left, and more hemoglobin is bound by CO than it is by oxygen. Using a CO pulse oximetry is the best way to evaluate for CO poisoning. However, this is not always available. Standard pulse oximetry is more readily available but is not always reliable since standard devices *are unable to differentiate* between oxygen and carbon monoxide bound to hemoglobin. Arterial blood gases will demonstrate a normal PaO₂ and decreased SaO₂, and CO-Hb levels may be directly obtained from both arterial and venous blood sampling. CO poisoning is not a consumptive or destructive process, so hemoglobin would not be expected to change.

How Do You Diagnose a Burn Wound Infection?

Burn wound infections comprise a spectrum of states from wound colonization to actual invasive infection with cellulitis and even necrotizing skin and soft tissue infection. Diagnosis of burn wound infections by clinical signs and symptoms alone is difficult and variable but include factors such as burn wound conversion, surrounding erythema, suppuration, and systemic manifestations (e.g., fevers, tachycardia, etc.). Patients with large burns (>20% TBSA) have higher risk for burn wound infection. Quantitative culture of a punch biopsy demonstrating >10⁵ bacteria/g of tissue is still considered by many to be the “gold standard.”

Management

How Would You Manage a Patient with Inhalational Injury?

Early intubation to prevent sudden loss of the airway due to the thermal injury and upper airway edema.

How Do You Calculate the Appropriate Volume of Fluid Resuscitation for a Burn Victim in the First 24 h?

While several burn resuscitation formulas and adjuncts exist, the Parkland formula is commonly used to calculate the amount of volume resuscitation necessary for a patient with second- or third-degree burns involving more than 20% TBSA. One-half of the total fluid volume should be administered in the first 8 h *from the time of injury* and the second half in the subsequent 16 h.

Parkland Formula

$$\begin{aligned} \text{Total fluid volume} \\ = 4\text{cc} / \text{kg} \times \text{weight (kg)} \times \text{TBSA (\%)} \end{aligned}$$

Watch Out

Urine output is a well-established parameter for guiding fluid management. The rate of fluid administration is titrated to a urine output of 0.5–1 mL/kg/h in adults and 2–4 mL/kg/h in kids. Hourly monitoring and appropriate titration of fluid is important for successful burn resuscitation.

What Is the Management for CO Poisoning?

All these patients should be started on 100% oxygen via non-rebreather face mask.

What Type of Fluid Should Be Used Acutely in a Burn Patient?

Lactated Ringer's. Traditionally, colloid solutions (e.g., albumin) were thought to increase pulmonary/respiratory complications within the first 24 h of a burn injury and were avoided. However, this may not be true as the evidence for this is poor. Burn surgeons have been utilizing colloids (albumin and plasma) within the first 24 h for patients not responding to crystalloid alone in an effort to restore intravascular volume and avoid abdominal compartment syndrome associated with excessive fluid volumes. More research is needed to delineate the role of colloids.

Watch Out

Normal saline is not recommended for burn resuscitation. With 154 mEq/L of Na⁺ and Cl⁻, the high volumes needed will lead to hyperchloremia and metabolic acidosis (as HCO₃⁻ will be excreted to balance the excess Cl⁻).

What Electrolyte Abnormality Must Be Closely Monitored in Burn Patients?

Burn patients should be monitored for abnormalities in serum sodium and potassium. Although hyponatremia can be related to the burn itself, it is often iatrogenic. While the Parkland formula can help calculate the fluid needs in burn patients, it cannot account for the subsequent compartmental fluid shifts that disrupt normal electrolyte levels. Hyponatremia can increase the risk of developing seizures in burn patients. Hyperkalemia can develop from the

destruction of cells and tissues and can lead to cardiac conduction abnormalities.

Watch Out

Succinylcholine is often used as an induction agent during rapid sequence intubation for trauma. In patients with significant burn injuries and subsequent release of potassium systemically, succinylcholine can cause life-threatening hyperkalemia leading to fatal arrhythmia and should be avoided. Non-depolarizing neuromuscular blocking agents such as rocuronium or vecuronium should be used in these cases. Other injuries leading to hyperkalemia include crush injury and significant muscle, soft-tissue, and skeletal trauma.

What Should Be Done for a Patient with a Circumferential Chest Burn and Deteriorating Respiratory Status?

Chest escharotomy. This is performed by incising the constricting eschar, thereby improving chest wall compliance and respiration. Unlike a fasciotomy, escharotomy only involves incisions through the burned skin, into the superficial fat, and not the deeper underlying structures. This procedure is relatively painless as the nerve endings in the dermis are already damaged by the burn injury. In emergent circumstances it can be done at the bedside. Extremity escharotomies should also be considered in patients with full-thickness circumferential burns with evidence of compromised perfusion.

What Are the Other Indications for Escharotomy?

Circumferential deep burns and neurovascular compromise of the extremity (e.g., weak pulse, decreased capillary refill, motor weakness, and decreased sensation).

How Do You Manage Burn Wounds?

Following the institution of resuscitative measures, local treatment of burn wounds involves cleansing, non-excisional debridement, and application of antimicrobial agents and dressings. Tangential excision of full thickness burns is indicated. Skin grafting (autografting) is performed for wounds too large to heal by contraction or primary closure after the wound bed is deemed clean and viable. Skin grafts are contraindicated if there is evidence of infection. Skin grafts may be partial-thickness (split-thickness skin graft, STSG) or full-thickness (FTSG) and dependent on several cosmetic and functional factors.

Should All Burn Patients Be Started on Prophylactic IV Antibiotics?

No. There have been no studies demonstrating the efficacy of prophylactic IV antibiotics in reducing burn wound infections. Instead, they are thought to select for resistant organisms.

What Topical Burn Agents Are Commonly Utilized in Burn Patients?

Table 47.3

Agent	Comments
<i>Silver sulfadiazine (Silvadene)</i>	Commonly used topical burn agent; may result in granulocyte reduction (neutropenia and thrombocytopenia); poor deep tissue penetration and <i>ineffective</i> against <i>Pseudomonas</i>
<i>Sulfamylon or mafenide acetate</i>	Dispensed in a cream and a solution; it functions as a carbonic anhydrase inhibitor and may result in <i>metabolic acidosis</i> ; deep tissue penetration and <i>effective</i> against <i>Pseudomonas</i> ; may be painful in application
<i>Silver nitrate</i>	Poor deep tissue penetration and <i>ineffective</i> against <i>Pseudomonas</i> ; brown staining of skin is common, electrolyte abnormalities (hyponatremia, hypokalemia) and methemoglobinemia may occur

What Medication Should All Burn Patients Be Started on to Prevent Curling's Ulcers?

Proton pump inhibitors or H₂ blockers.

Can Patients with Severe Burn Injuries Be Fed Orally? Why or Why Not?

In general, the enteral route is the *preferred* method of delivery of nutrition. Early initiation of enteral nutritional support (<12 hours after injury) is recommended if the patient is hemodynamically stable. There is evidence of improved tolerance to feeding and amelioration of the hypermetabolic response with early initiation. Intra gastric feeding is acceptable though enteral feeding into the small intestine is preferred, especially for patients with very large burn injuries. In patients in whom enteral tube feedings are not tolerated, parenteral nutrition should be considered.

What Are the Principles of Management for Chemical Burns?

Protection of others from exposure and removal of patients from area of exposure. Following removal of all clothing, dry chemicals should be brushed off the patient. With few exceptions, copious irrigation with water is the most important principle in the management of chemical burns. The longer the acid/alkali material stays in contact with the patient's body, the worse the prognosis is.

What Is the Key Management Principle for Patients with Electrical Burns?

Cardiac monitoring for 12–24 h to look for arrhythmias, particularly when a high-voltage injury (>1000 V) is suspected. In general, patients with a normal electrocardiogram (ECG) after low-voltage exposure do not require 24 h of cardiac monitoring.

Is There Benefit to Reducing the Hypermetabolic State of Burn Patients?

In children with burns, treatment with propranolol during hospitalization attenuates hypermetabolism and reverses muscle-protein catabolism. There is evidence of similar benefit in adults.

Areas You Can Get in Trouble

Child Abuse

Burn injuries account for a minority of child abuse cases but should be considered for all children presenting with burn marks characterized by sharply demarcated margins or deep localized contact injury (e.g., cigarette burn). Children with non-accidental burns are almost always less than 10 years of age, and the majority is less than 2 years of age. Toilet training is a particularly vulnerable time. Caregivers in this setting may provide inconsistent histories or conflicting accounts of how their child received the burn injury.

Chronic Non-healing Wound

Patients with chronic non-healing wounds are at increased risk for the development of squamous cell carcinoma of the skin (Marjolin's ulcer). All chronically non-healing wounds should be evaluated with a skin biopsy.

Summary of Essentials

History and Physical

- First degree (superficial), second degree (superficial and deep partial thickness), third degree (full thickness), and fourth degree.
- Superficial partial thickness (painful) and full thickness (little or no pain).
- Severity of burns determined by TBSA approximated by rule of 9s:
 - Head, 9%; each arm, 9%; anterior torso, 18%; posterior torso, 18%; each leg, 18%
 - Only count second- or third-degree burns (not first)
- Carbonaceous sputum indicates possible inhalational injury.

Pathophysiology

- Thermal, chemical, and electrical.
- Loss of skin barrier increases risk of fluid and temperature deregulation:
 - Hypovolemic shock
 - Infection
- Increased age, TBSA, and inhalational injury are risk factors for mortality.

Workup

- Inhalational injury:
 - Clinical suspicion by presence of facial burns, singed nasal hairs, and history of injury in an enclosed space
 - Fiberoptic bronchoscopy for definitive diagnosis
- Burn wound infection:
 - Punch biopsy demonstrating $>10^5$ bacteria/g

Management

- Parkland formula:
 - Total fluid volume = $4 \text{ mL/kg} \times \text{weight (kg)} \times \text{TBSA (\%)}$, administer 1/2 total in first 8 hrs; use lactated Ringer's.
 - Titrate urine output to 0.5–1 mL/kg/h in adults and 2–4 mL/kg/h in kids.
- Non-excisional debridement and topical antibacterial agents for initial wound care followed by serial tangential excision and grafting for full-thickness burns

Suggested Reading

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Severe Right Leg Pain After Tibia Fracture

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Case Study

A 30-year-old male is brought to the emergency department by paramedics after a motorcycle accident. He has an obvious deformity of the right lower extremity below the knee. Imaging reveals a fracture of the tibia and fibula. He is taken to the operating room for an open

reduction and internal fixation (ORIF). Approximately 8 hours after surgery, the patient complains of severe pain in his right leg. On physical examination, the right leg is tensely swollen. He endorses severe tenderness on palpation, especially lateral to the tibia. When his ankle is passively

dorsiflexed, he grimaces in pain. His foot appears pink and well perfused. Pulses in the dorsalis pedis and posterior tibial are 2+ and Doppler interrogation demonstrates biphasic signals in both arteries. Sensory exam of the right foot is intact except for numbness in the first web space.

Diagnosis

What Is the Differential Diagnosis?

Table 48.1

Diagnosis	Comments
Compartment syndrome	Pain out of proportion to exam, particularly with passive motion of the ankle; tense leg edema, recent trauma, pulse usually present
Necrotizing soft tissue infection (NSTI)	Acute infection of the skin, fascia, or muscle, often with exam findings of crepitus, bullae, and necrosis of subcutaneous tissue; often mixed bacterial flora
Cellulitis	Superficial infection of the skin presenting with redness and erythema
Deep vein thrombosis	Calf pain, leg edema; risk factors include prolonged stasis, hypercoagulable state, and endothelial injury (<i>Virchow's triad</i>)
Acute limb ischemia	Pain, pallor, pulselessness (pulse always absent), paresthesias, paralysis, and poikilothermia; history of claudication, arterial insufficiency or atrial fibrillation, trauma (posterior knee dislocation, tibial fracture)

What Is the Most Likely Diagnosis?

In a patient presenting with a tense, tender leg following ORIF, with pain on passive dorsiflexion and tenderness upon palpation of the compartments, the most likely diagnosis is a lower extremity compartment syndrome.

History and Physical

What Are the Six Ps of Compartment Syndrome? How Do These Ps Differ from Acute Limb Ischemia?

Compartments are relatively inflexible tissue envelopes throughout the body with poor compliance. Acute changes in volume or extrinsic compression can result in elevation in

compartment pressure, producing diminished capillary filling pressure. The resulting tissue ischemia produces the 6 Ps: **pain**, **paresthesia**, **pallor**, **paralysis**, **pulselessness**, and **pressure** (swollen or tense compartment). Acute limb ischemia produces similar symptoms and signs, though loss of a pulse is an *early* finding, and the extremity is not typically tensely swollen. In compartment syndrome, pulselessness is a *late* sign.

What Are Considered Early Symptoms/Signs of Compartment Syndrome?

As compartment pressures increase, the first symptom that manifests is pain, especially with passive range of motion. Continually elevated compartment pressures will result in tense swelling (pressure) and nerve ischemia, producing a sensory deficit (paresthesia) that usually precedes motor deficits. As capillary refill continues to diminish, pallor and paralysis.

What Is Meant by Pain Out of Proportion to the Physical Exam Findings (Clinical Situation)?

The tense swelling of muscles in a compartment may eventually lead to ischemic necrosis, which manifests as marked pain in the affected extremity. However, the physical exam and clinical scenario may be deceptively benign. The foot itself often appears pink and well perfused. Pulses are almost always present (as in the present case). Thus, an unsuspecting clinician may be reassured that the pain is simply from the bone fracture. Compartment syndrome remains a clinical diagnosis and severe extremity pain after injury mandates careful evaluation.

Watch Out

Pain out of proportion to the exam is also a feature of acute mesenteric ischemia classically due to an embolus to the superior mesenteric artery in the setting of atrial fibrillation.

Anatomy

How Many Compartments Are There in the Upper Leg (Thigh)? Lower Leg? Upper Arm? Forearm?

Table 48.2

Extremity	Number	Names
Upper leg (thigh)	3	Anterior, medial, posterior
Lower leg	4	Anterior, lateral, superficial posterior, deep posterior
Upper arm	2	Anterior, posterior
Forearm	3	Dorsal, volar, mobile wad

Pathophysiology

How Are the Etiologies of Compartment Syndrome Classified?

They can be classified as those that restrict (or decrease) compartment size or those that cause increased intra-compartment volume against the relatively inelastic fascial envelopes. Regardless of the cause, the end point is decreased capillary perfusion and tissue ischemia.

Etiologies of Compartment Syndrome

- Decreased compartment size
 - Plaster casts
 - Circumferential third-degree burn
 - External compression
 - Military anti-shock garments
 - Splints
- Increased compartment volume
 - Vascular injury
 - Blast injury
 - Bone fracture
 - Crush injury
 - Electrical burns
 - Hematoma/bleeding
 - Ischemia/reperfusion
 - Sepsis

What Is the Pathophysiology of Compartment Syndrome?

Extremity compartment syndrome is typically preceded by an extremity injury, such as a crush, burn, fracture, or reper-

fusion event. Acute inflammatory mediators result in increased capillary permeability and interstitial accumulation of fluid, leading to an elevation of compartment pressure. Alternatively, an injury can cause bleeding into the compartment, which produces both an increase in volume and pressure. Normal compartment pressures range from 5 to 10 mmHg. As pressures exceed this normal range, venules collapse and venous hypertension results. As the arterial-venous pressure gradient diminishes, capillary perfusion is compromised producing tissue ischemia. If uncorrected, compartment syndrome can lead to advanced tissue necrosis and potentially resulting in permanent neurologic deficits or systemic illness.

Watch Out

Tissue damage secondary to compartment syndrome can result in hyperkalemia, acidosis, and myoglobinuria, which can cause end-organ damage, most commonly kidney failure.

How Does Chronic Compartment Syndrome Differ from Acute Compartment Syndrome?

Chronic or exertional compartment syndrome is a less common entity. It is the result of tissue edema produced during *exertional activity*, leading to swelling and pain within the compartment. Symptoms typically resolve with rest and are milder than those seen with acute compartment syndrome. Patients often have a long history of this condition and the diagnosis is based on clinical history and presentation. Chronic compartment syndrome is not a surgical emergency but, like acute compartment syndrome, can be treated with fasciotomy if symptoms are severe.

What Is the Significance of the First Web Space Numbness?

For lower leg injuries, the anterior compartment is most susceptible to compartment syndrome. The *deep peroneal nerve* courses within this compartment and supplies motor fibers to the extensor digitorum brevis and extensor hallucis brevis, as well as afferent cutaneous sensation for the first web space. Nerve ischemia within the anterior compartment thus produces characteristic numbness between the first and second toes.

What Is the Implication of Pulselessness in the Setting of Compartment Syndrome?

The pathogenesis of compartment syndrome involves diminished arterial-venous pressure gradients and microvascular

compromise. The increase in compartmental pressure required to develop compartment syndrome is not generally sufficient to occlude arterial flow. Thus, pulselessness is not a feature of compartment syndrome. An absent pulse in the setting of compartment syndrome would imply extremely high compartment pressures and likely very advanced, irreversible tissue ischemia.

What Is Volkmann's Ischemic Contracture?

Volkmann's ischemic contracture is a sequela of untreated compartment syndrome. It is classically seen in children following a supracondylar fracture that leads to marked swelling of the forearm muscles. An associated brachial artery injury from the fracture may also lead to ischemia and a compartment syndrome may result. Untreated, the compartment syndrome leads to ischemic muscle that becomes fibrosed and contracted. The eventual result is a clawlike hand with flexion of the hand at the wrist as well as damaged and insensate nerves.

What Is the Pathophysiology of the Various Types of Compartment Syndrome?

Table 48.3

Example	Underlying cause of compartment syndrome
<i>Circumferential third-degree burn</i>	Eschar from burn reduces compartment size while simultaneous capillary leak from injury and fluid resuscitation increases compartment volume
<i>Ischemia/reperfusion</i>	Reperfusion produces multiple inflammatory mediators, increasing vascular permeability and compartment edema
<i>Large-volume resuscitation</i>	Third spacing of intravascular fluid into the interstitial space increases compartment swelling
<i>Severe exertion</i>	Exertional activity causes tissue edema and increases compartment pressure in susceptible patients
<i>Severe hypotension</i>	Resulting systemic inflammatory mediators and capillary leak increase compartment edema and also lead to ischemia/reperfusion injury
<i>Prolonged surgery/immobilization</i>	Crush injury can occur with prolonged immobilization, resulting in local inflammation, capillary leak, and compartment edema

What Is Abdominal Compartment Syndrome? What Are the Risk Factors?

The abdominal cavity, like the extremities, is contained in a fascial envelope and is therefore susceptible to elevated pressures. Patients with multiple traumatic injuries, particularly intra-abdominal or retroperitoneal, who have received large volume of fluids and blood products, are at risk of developing intra-abdominal hypertension (IAH) which can progress to abdominal compartment syndrome (ACS). ACS should be suspected in any severely injured patient who demonstrates decreased urine output, increasing peak airway pressures on the ventilator, and increasing vasopressor support, in the absence of another identifiable cause.

Workup

How Is the Diagnosis of Compartment Syndrome Established in an Extremity?

The diagnosis of extremity compartment syndrome is chiefly clinical and is based on the aforementioned findings of tense, tender, swollen compartments with pain on passive motion. With the classic history and physical examination, no further workup is necessary.

What Is the Role of Measuring Compartment Pressures with Suspected Extremity Compartment Syndrome?

In the presence of history and physical examination findings consistent with extremity compartment syndrome, measurement of compartment pressures is unnecessary. Such measurements can be inaccurate and may lead to a false-negative result. Compartment pressures should only be considered in cases where patients are not able to provide a reliable exam (e.g., obtunded or intoxicated patient). A normal extremity compartment pressure is 5–10 mmHg. Most authors advocate decompression in patients with a pressure of >25–30 mmHg.

How Is Abdominal Compartment Syndrome Diagnosed?

Abdominal compartment syndrome is not reliably defined on physical exam, as patients with this condition are often intubated. Indirect measurement of abdominal pressures may be performed by transducing a bladder pressure. Intrabdominal hypertension (a precursor to compartment syndrome) is defined by pressure ≥ 12 mmHg, while abdominal compartment syndrome is defined by pressure ≥ 20 mmHg associated with new organ dysfunction, such as oliguria.

Management

What Is the Treatment of Extremity Compartment Syndrome?

Treatment is immediate decompressive fasciotomy of all the compartments of the affected limb.

If Compartment Syndrome Is Suspected in Only One Compartment of the Lower Leg, Why Is Fasciotomy Performed for All Four Compartments?

It is difficult to reliably rule out the absence of compartment syndrome in one compartment if another is affected. Furthermore, compartment syndrome may not be fully manifested in other compartments at the time of surgery but may develop later. Therefore, fasciotomy of *all compartments* of the affected limb should be performed.

What Compartment in the Lower Leg Is Most Often Missed During Fasciotomy?

The deep posterior compartment is the most difficult to release and is most often missed. Decompression of this compartment is vital for long-term foot function, as it contains both the posterior tibial and peroneal arteries and the tibial nerve.

Watch Out

The superficial peroneal nerve is the most common nerve injured during lower extremity fasciotomy resulting in inability to evert the foot. This can be avoided by ending the lateral fasciotomy about 5 cm below the fibular head.

What Is the Treatment of Abdominal Compartment Syndrome?

Treatment is urgent decompressive laparotomy, with maintenance of an open abdomen and coverage with a vacuum-assisted suction device. Delayed closure of the abdomen is accomplished when acute edema improves, and fascial closure can be accomplished without reproducing intra-abdominal hypertension. In cases of ascites leading to compartment syndrome, it is reasonable to attempt paracentesis first.

Complications

What Complications Can Occur from Lower Leg Fasciotomy?

Table 48.4

Complication	Comments
Wound infection	This is the most common complication and can occur in as many as 40% of cases, likely multifactorial due to tissue necrosis and open wound
Superficial peroneal nerve injury	Passes superficially in lateral compartment and easily injured during procedure, resulting in inability to evert the foot
Incomplete fasciotomy	Inadequate fascial incisions prohibit complete decompression of the compartment; generous skin and fascial openings are needed to fully decompress the leg
Chronic swelling	Can contribute to diminished limb function

Summary of Essentials

History and Physical

- Severe pain, tense swollen compartments
- Pain worsens with passive motion
- Pain out of proportion to clinical exam
- The six Ps: pain, pressure, pallor, paralysis, and pulselessness
 - Pulselessness is a very late sign in compartment syndrome.
 - The six Ps are not consistently present.

Pathophysiology

- Decreased compartment size
 - Casts, circumferential burn, compression dressing, anti-shock garments, and splints
- Increased compartment volume
 - Trauma (bleeding, muscle swelling)
 - Ischemia/reperfusion

Workup

- In the presence of a classic history and physical examination, no further workup is needed.
- Measure compartment pressures only if diagnosis is in doubt.
 - Normal pressure is 5–10 mmHg.
 - Intervention if >25–30 mmHg.

Management

- Immediate decompressive fasciotomy of all the compartments of the affected area of the limb

Prognosis

- Delay recognition/treatment may lead to limb loss, hyperkalemia, acidosis, and renal failure.

Suggested Reading

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Question Set: Trauma

Questions

1. An 18-year-old man presents to the emergency department after a stab wound to the chest. He is combative and with severe shortness of breath. His blood pressure is 94/76 mmHg with a pulse of 120/min and respiratory rate of 28/min. Physical exam reveals a 2 cm stab wound on the left chest. Lung fields on the left have decreased breath sounds and are hyperresonant to percussion. His neck veins are distended. A needle is placed in the left second intercostal midclavicular line and aspirated until a gush of air is heard escaping the chest wall. A liter of normal saline is given, and blood pressure improves to 120/70 mmHg, and pulse decreases to 100/min. What is the best next step in management?
- (A) Transfuse O-negative blood
 - (B) Tube thoracostomy
 - (C) Chest x-ray
 - (D) CT scan of the chest
 - (E) Transport to the operating room for exploratory thoracotomy
2. A 25-year-old male suffers a gunshot wound to his right mid-thigh. On physical examination, there is no hematoma, no palpable thrill, and no bleeding from the wound. He has diminished but present pedal pulses on the right and normal pulses on the left. Neurological exam is normal. Ankle-brachial index on the right is 0.8 and 1.0 on the left. What is the next step in the management?
- (A) Surgical exploration of the leg
 - (B) CT angiography
 - (C) Formal angiography
 - (D) Observation
 - (E) Systemic heparinization
3. A 58-year-old intoxicated man presents to the emergency department after getting struck by a vehicle. His blood pressure on arrival was 98/55 mmHg with a pulse of 120/min. Following fluid resuscitation, his blood pressure increases to 120/70 mmHg, and pulse decreases to 80/min. His abdomen is distended and mildly tender, and he has no obvious source of blood loss. A CT scan of the abdomen and pelvis shows no intraperitoneal fluid but demonstrates bilateral pelvic fractures and a large pelvic fluid collection adjacent to the fracture with a contrast blush within it. What is the best next step in management?
- (A) Military anti-shock trousers (MAST)
 - (B) External pelvic fixation
 - (C) Open reduction and internal fixation of pelvic fracture
 - (D) Exploratory laparotomy
 - (E) Emergency angiography with embolization
4. A 30-year-old male presents to the emergency department with a gunshot wound to the right chest, just above his right nipple. He complains of shortness of breath and severe right chest pain. His blood pressure is 110/70 mmHg, heart rate is 100/min, and respiratory rate is 20/min. His breath sounds are slightly diminished on the right. The trachea is midline. Neck veins are flat. The abdomen is non-tender. Upper extremity pulses are equal. A chest x-ray demonstrates a moderate right hemo- and pneumothorax. The bullet is seen in the upper chest. A chest tube is inserted into the right

chest with an immediate output of 500 cc of dark blood, and after which the bleeding appears to slow down. What is the next step in the management?

- (A) Exploratory right thoracotomy
- (B) Video-assisted thoracoscopic surgery (VATS)
- (C) Admit to ICU for observation
- (D) Repeat chest x-ray
- (E) CT of the chest and abdomen

5. A 28-year-old man arrives to the emergency department following a high-speed motor vehicle accident. He is in severe pain and breathing rapid shallow breaths. His blood pressure is 80/60 mmHg, heart rate is 120/min, and respiratory rate is 30/min. A segment of his right anterolateral chest wall exhibits paradoxical inward motion on inspiration. Despite supplemental oxygen, the respiratory rate remains the same. Breath sounds are equal bilaterally. The trachea is midline. What is the next best step in management?
- (A) 2 L bolus of normal saline
 - (B) Insert a right needle thoracostomy
 - (C) Endotracheal intubation
 - (D) Transfuse two units of O-negative blood
 - (E) Place tube thoracostomy (chest tube) on the right
6. Which of the following parameters would be most consistent with acute carbon monoxide poisoning?
- (A) Hemoglobin decreases
 - (B) PaO₂ decreases
 - (C) Oxygen content of blood decreases
 - (D) Oxidized hemoglobin increases
 - (E) Increased alveolar ventilation
7. Which of the following clinical scenarios is the best indication for four-compartment lower extremity fasciotomies?
- (A) After a crush injury with an open tibia and fibula fracture
 - (B) After successful revascularization of a leg that was ischemic for 6 hours
 - (C) After repair of a femoral artery injury due to a gunshot wound to the leg
 - (D) After repair of a combined popliteal artery and vein injury due to a gunshot injury
 - (E) After an electrical burn, with a tensely swollen and tender leg and numbness in the first web space
8. A 30-year-old male arrived via paramedics after getting struck in the abdomen by a golf cart while vacationing with his family. He had no head trauma and only complained of mild abdominal pain. His vitals were normal and stable. A CT scan revealed no abnormal findings, and he was discharged on the same day. Three days later, he comes back to the emergency department complaining of fevers, nausea, poor appetite, and abdominal pain. A repeat CT scan shows a laceration at the neck of the pancreas with disruption of the pancreatic duct. What is the best next step in management?
- (A) Order serum amylase
 - (B) Endoscopic retrograde cholangiography (ERCP)
 - (C) CT-guided drainage
 - (D) Magnetic resonance cholangiopancreatography (MRCP)
 - (E) Exploratory laparotomy
9. A 40-year-old man involved in a motor vehicle collision with a drunk driver on the freeway is brought to the emergency department. He has a dark bruise from his seat belt across the left side of his neck. On physical examination, he is neurologically intact. However, his left eyelid is drooping, and his left pupil is constricted as compared to his

right. CT scan with contrast demonstrates dissection of the left internal carotid that extends into the base of the skull. CT of the head and abdomen are negative. Which of the following would be the most appropriate management?

- (A) Left neck exploration
- (B) Subtherapeutic heparin administration
- (C) Carotid stenting
- (D) Thrombolytic therapy
- (E) Observation

10. A 22-year-old male arrives to the emergency department by paramedics with a gunshot wound in the right upper quadrant of his abdomen. He is anxious and complains of pain near his wound. His temperature is 37.8 °C, blood pressure is 114/78 mmHg, and pulse is 90/min. His abdomen is soft, and he has no rebound or guarding. A portable chest x-ray is normal, and nasogastric tube (NG) tube demonstrates clear fluid with no blood. His rectal examination shows no blood. What is the most appropriate next step in management?
- (A) Serial physical examination
 - (B) Exploratory laparotomy
 - (C) CT scan of the abdomen
 - (D) Diagnostic peritoneal lavage (DPL)
 - (E) Focused assessment with sonography for trauma (FAST)
11. A 62-year-old man with atrial fibrillation presents to the emergency department with a painful right lower leg. He has refused warfarin in the past. His physical exam is significant for an irregularly irregular heart rate and a painful right leg that is cool to touch with absent distal pulses. Pulses in the left foot are normal. He has significant motor weakness and sensory deficit in the right foot. Duplex scan reveals an occlusion of the right popliteal artery. He receives heparin and undergoes open surgical embolectomy. Following the procedure, his motor and sensory deficit dramatically improves. The next day, he experiences intense pain in the right calf. His right calf is swollen and tense, and the pain is worsened with passive dorsi- and plantar flexion of his right foot. He has palpable distal pulses. What is the most likely underlying etiology for his acute condition?
- (A) Interstitial edema
 - (B) Recurrent embolization
 - (C) Deep vein thrombosis (DVT)
 - (D) Atherosclerotic plaque
 - (E) Lymphedema
12. Burn patients are at risk for multiple infections. What is the most common organism to cause infection in burn patients?
- (A) *Klebsiella*
 - (B) *Streptococcus pyogenes*
 - (C) *Streptococcus agalactiae*
 - (D) *Pseudomonas aeruginosa*
 - (E) *Candida albicans*
13. A 10-year-old boy presents to the emergency department with severe abdominal pain after falling over his bicycle handles while attempting a trick. A CT scan shows oral contrast extravasation into the retroperitoneum that is coming from the posterior aspect of the duodenum. Which of the following is the best management recommendation?
- (A) Laparoscopy
 - (B) Exploratory laparotomy
 - (C) Observation
 - (D) Upper endoscopy to confirm injury
 - (E) CT-guided drainage

14. A 40-year-old alcoholic presents to the emergency department with a markedly swollen right forearm that is diffusely tender. He states that following an alcohol and heroin binge, he fell asleep on his arm for 12 hours. He woke up to find his hand completely numb and unable to move it. On physical exam, he has normal brachial and radial pulses. His heart has a regular rate and rhythm. He is unable to extend his wrist when the hand is palm down. Electrocardiogram reveals peaked T-waves, and creatine kinase level is 20,000 IU/L (normal, 60–400 IU/L). What is the next step in management?
- (A) Propranolol
 - (B) Insulin + dextrose
 - (C) Calcium gluconate
 - (D) Kayexalate (sodium polystyrene)
 - (E) Furosemide
15. A 5-year-old girl arrives to the emergency department with complaints of nausea, vomiting, and abdominal pain for the past day. She has no significant past medical history, but her mother reports that she was involved in a motor vehicle accident about a month ago. She was restrained in a car seat and had blunt trauma to her abdomen. She had no complaints at the time. Her vital signs were normal, and she was subsequently discharged a few hours later. Her blood pressure is currently 112/82 mmHg, pulse is 90/min, and respiratory rate is 28/min. Her chest x-ray is shown above (■ Fig. 1). What is the most likely diagnosis?



■ Fig. 1 Chest x-ray (From Yamamoto H, Parikh DH. *Pediatr Surg Int*. 2005;21(12):1021–2. Reprinted with permission)

- (A) Gastroenteritis
 - (B) Diaphragmatic hernia
 - (C) Delayed splenic rupture
 - (D) Hemothorax contusion
 - (E) Pneumonia
16. A 32-year-old female is stabbed in the right lateral neck 1 cm above the clavicle. There is an expanding hematoma in her neck, and she is having great difficulty speaking. Breath sounds are absent on the right. Subcutaneous air is noted in her neck. What is the next step in management?
- (A) Intubation
 - (B) Chest tube placement
 - (C) Duplex ultrasound of the carotid
 - (D) Operative repair
 - (E) Esophagoscopy

17. A 25-year-old male arrives to the emergency department with a stab wound lateral to his umbilicus after being involved in a drunken fight at a local bar. You can smell alcohol on his breath, and he is uncooperative during the exam. His temperature is 37.8 °F, blood pressure is 90/60 mmHg, and pulse is 120/min. His abdomen is soft, non-tender with no rebound or guarding. What is the most appropriate next step in management?
- (A) Exploratory laparotomy
 - (B) Local wound exploration
 - (C) CT scan of the abdomen
 - (D) Serial physical examination
 - (E) Focused assessment with sonography for trauma (FAST)
18. In a patient presenting with acute limb ischemia in the right leg, what is the first structure to develop ischemic changes?
- (A) Fat
 - (B) Nerve
 - (C) Muscle
 - (D) Skin
 - (E) Bone
19. A 25-year-old football player presents to the emergency department after sustaining a devastating tackle and hyperextension of his right knee. The knee appears to be posteriorly dislocated and the leg is swollen. Pedal pulses on the right appear to be diminished but present, whereas they are normal on the left. The remainder of his exam does not reveal any obvious signs of bleeding. What is the appropriate next step in management?
- (A) Fasciotomy of all four compartments of the lower leg
 - (B) CT angiography
 - (C) Immediate heparinization
 - (D) Plain film of the knee, followed by reduction of the dislocation
 - (E) MRI of the knee
20. A 30-year-old unrestrained driver is brought in by paramedics after a high-speed motor vehicle accident. In the emergency department, his heart rate is 110/min and blood pressure is 104/75 mmHg and decreases to 92/68 mmHg during inspiration. His tachycardia and hypotension persist despite aggressive fluid resuscitation. He appears pale, and his neck veins are distended. He has multiple bruises on his chest and abdomen. His chest x-ray is unremarkable. What is the most likely diagnosis?
- (A) Aortic transection
 - (B) Cardiac tamponade
 - (C) Severe lung contusion
 - (D) Tension pneumothorax
 - (E) Diaphragm injury
21. A 38-year-old obese construction worker arrives to the trauma bay after accidentally getting struck by a bulldozer at his job site. In the emergency department, his mental status is altered, with a Glasgow Coma Scale (GCS) score of 10. His blood pressure is 80/66 mmHg with a pulse of 112/min. He is given 2 L of intravenous fluids, but his blood pressure and pulse remain the same. A focused assessment with sonography for trauma (FAST) is inconclusive. A portable chest x-ray is negative, and a pelvic x-ray demonstrates bilateral pubic rami fractures. What is the best next step in management?
- (A) Diagnostic peritoneal lavage (DPL)
 - (B) Pelvic angiography with possible embolization
 - (C) Exploratory laparotomy
 - (D) Head CT scan
 - (E) Abdominal CT scan

22. A 25-year-old male is at a pool party and is heavily intoxicated. He dives into the shallow end of the pool and is subsequently found to be floating face down in the pool. He is rushed to the emergency department by paramedics in a cervical collar. He opens his eyes, nods his head appropriately to questions, and his pupils are equally round and reactive to light. However, he is not moving his arms or legs. There is no evidence of external bleeding. His blood pressure is 85/45 mmHg, and his heart rate is 70/min. Which of the following would most likely be seen in association with the injury described?
- (A) Low cardiac output
 - (B) Elevated systemic vascular resistance (SVR)
 - (C) Priapism
 - (D) Parasympathetic blockade
 - (E) Lumbar spine injury
23. A 45-year-old male construction worker is digging a trench when he cuts his arm on a rusty nail in the soil. He has not been to the doctor since he was a teenager, but he is confident he received all of his vaccinations up to age 18. What is the next step in treatment?
- (A) Tetanus immunoglobulin only
 - (B) Tetanus vaccination only
 - (C) Tetanus immunoglobulin and vaccination
 - (D) Primary wound closure
 - (E) Clindamycin for 3 weeks
24. A 7-year-old boy presents to his pediatrician with a tense, painful, weak, and shortened forearm with a claw-like deformity of the hand. The mother states that 1 year earlier, the child fell backward on his outstretched hand and suffered a supracondylar fracture that was treated with closed reduction and casting. The most likely explanation for the current physical exam findings is:
- (A) Nerve entrapment
 - (B) Suppurative tenosynovitis
 - (C) Ischemia/necrosis of forearm muscles
 - (D) Complex regional pain syndrome
 - (E) Improperly reduced fracture
25. A 65-year-old former firefighter arrives for follow-up for chronic wound in his right leg from a burn he suffered 25 years earlier. The wound has failed to heal despite repeat skin grafting. Recently, the wound has become more painful and larger, measuring 2×2 cm, and continuously drains. Multiple biopsies of the wound are taken. Which of the following is the most important contributing factor to this patient's presenting condition?
- (A) Radiation exposure
 - (B) Excess UV light exposure
 - (C) Work-related exposure to heavy metals
 - (D) Genetic predisposition
 - (E) Chronic inflammation
26. A 25-year-old man arrives to the emergency department following a motor vehicle accident with multiple abrasions on his abdomen. His blood pressure is 90/60 mmHg, and his pulse is 120/min. After a primary survey, a focused assessment with sonography for exam is performed. Which of the following is a focused assessment with sonography for trauma (FAST) poor at detecting?
- (A) Pericardial effusion
 - (B) Single pneumothorax
 - (C) Free peritoneal fluid in the hepatorenal space (Morrison's pouch)
 - (D) Laceration of the kidney with perinephric fluid
 - (E) Free peritoneal fluid in the perisplenic space

27. A 23-year-old male is rushed to the emergency department by paramedics after sustaining a gunshot wound to the lateral neck at the level of the thyroid cartilage. The patient is hemodynamically stable and is able to speak. Physical exam shows no signs of hematoma, pulsatile bleeding, thrill, or bruit. Which of the following is the next step in management?
- (A) Surgical exploration
 - (B) Wound closure
 - (C) CT angiography
 - (D) Intubation
 - (E) Formal angiography
28. A 41-year-old patient presents to the emergency department following a stab wound to the chest, just above the left nipple line. On initial exam, his blood pressure is 94/70 mmHg, and respiratory rate is 16/min. He has distended neck veins, and his heart sounds are muffled. A focused assessment with sonography for trauma (FAST) demonstrates fluid in the pericardial sac. What is considered the first sign of this condition?
- (A) Electrical alternans
 - (B) Impaired diastolic filling
 - (C) "Water-bottle" shape on chest radiograph
 - (D) Left ventricle cavity becomes smaller
 - (E) Distended neck veins
29. A pregnant woman in her second trimester arrives to the emergency department after a minor motor vehicle accident. She has no injuries or complaints but is worried that her pregnancy is in danger. She has a nonstress test that shows two accelerations of fetal heart rate, each at least 15 beats per minute above baseline and lasting at least 15 s. She has no contractions, vaginal bleeding, or abdominal pain. A focused assessment with sonography for trauma (FAST) is negative. What is the next best step in management?
- (A) Monitor the patient overnight
 - (B) Biophysical profile
 - (C) Discharge and follow-up in 2 weeks
 - (D) CT of the abdomen
 - (E) MRI of the abdomen
30. A 40-year-old policeman is brought to the emergency department having suffered burns after helping to rescue a woman from a burning warehouse. His temperature is 37.9 °C, blood pressure is 100/70 mmHg, pulse is 95/min, and respiratory rate is 24/min. On physical examination, he has 40% total body surface area deep partial and full-thickness burns to his face, arms, and back as well as a circumferential burn of his neck. He has singed nasal hairs, and there is carbonaceous sputum coming out of his mouth. His lungs are clear to auscultation bilaterally. Electrocardiogram demonstrates premature ventricular contractions. What is the most appropriate next step in management?
- (A) Broad-spectrum antibiotics
 - (B) Endotracheal intubation
 - (C) IV fluid resuscitation
 - (D) Cardiac enzymes and serial electrocardiogram
 - (E) Bronchoscopy
31. A 40-year-old depressed and schizophrenic man jumps off a three-story window onto the street. Paramedics arrive on scene within 5 min, and he is rushed to the emergency department but loses vitals in the field and is dead on arrival (DOA). What is the most likely cause of death?
- (A) Thoracic aortic transection
 - (B) Tension pneumothorax
 - (C) Abdominal aortic transection
 - (D) Ruptured spleen
 - (E) Pulmonary artery transection secondary to a jagged rib edge

Answers

✓ 1. Answer B

This patient has a left-sided tension pneumothorax as confirmed by hypotension, distended neck veins, decreased breath sounds, and hyperresonant left chest. Immediate treatment is with needle thoracostomy, allowing for immediate thoracic decompression. This is preferred in the setting of a tension pneumothorax as it is faster than a chest tube but provides only *temporary* relief. All these patients require a tube thoracostomy (chest tube) immediately following needle thoracostomy. Operative management is not routinely indicated for patients with tension pneumothorax as needle decompression and subsequent tube thoracostomy are able to resolve most cases (E). If he had a significant hemothorax that continued to hemorrhage despite tube thoracostomy, surgical management could be considered as well as blood products (A). Tension pneumothorax is considered a clinical diagnosis, and confirmation with imaging is not recommended as it delays definitive care in the unstable patient (C–D).

✓ 2. Answer B

Penetrating trauma to the extremities should be assessed for neurovascular injuries. Prompt surgical exploration would be indicated if the patient had *hard signs* of vascular injury (e.g., pulsatile bleeding, expanding hematoma) (A). It is important to note that a diminished pulse is considered a soft sign while an absent pulse is considered a hard sign. In the absence of hard signs, an ABI should be checked. If the ABI is <0.9 , suspicion for an arterial injury is high, and as such, imaging with CT angiography is the most appropriate management option. Formal angiography can be considered if CT results are equivocal (C). Observation would be appropriate if he had a normal ABI (D). Systemic heparinization is sometimes used during the course of arterial repair if the injury led to thrombosis and an interposition vein graft is used (E).

✓ 3. Answer E

This patient's mechanism of injury and blood pressure drop are highly suggestive of hemorrhagic shock. Given that the patient responded well to IV fluids, it is appropriate to obtain CT imaging to look for the source of bleeding. If the source was intra-abdominal bleeding, the next step would be exploratory laparotomy (D). However, the CT indicates that the source is pelvic bleeding, likely from the pelvic fracture. Such bleeding is best managed via emergent pelvic angiography, which could be diagnostic and therapeutic (with embolization). MAST suits were at one time popular as the compression was thought to tamponade bleeding (A). However, they have not been shown to be effective. External pelvic fixation can reduce and stabilize fractures and thus lead to a slowing of bleeding but is not considered as effective as angiographic embolization (B). Open reduction and internal fixation is the definitive treatment for a pelvic fracture (C). But given the technical difficulty and long length of such an operation, it is not recommended acutely and especially not in someone who is actively bleeding. Pelvic packing is emerging as an alternative to angiography for pelvic bleeding.

✓ 4. Answer D

This patient presents with a right hemo- and pneumothorax, and tube thoracostomy was able to evacuate 500 cc of dark blood. The most appropriate next step in management is to perform a repeat chest x-ray to ensure that the tube thoracostomy is in the right position and that the hemo- and pneumothorax have resolved. Exploratory right thoracotomy would be indicated only if the initial output after chest tube placement was >1500 cc or if the patient continued to bleed briskly (>200 cc/hour for 3 h) (A). VATS is indicated if the chest tube has inadequately drained the hemothorax and should be done early (within 2 days) to prevent an empyema (D). CT of the chest is generally not needed if the chest x-ray shows that the hemothorax is resolved, and CT of the abdomen is unnecessary at this time as the bullet entered just above the nipple (and thus above the diaphragm) and is visualized in the chest, thus sparing the abdominal cavity (E).

- ✓ 5. Answer C
This is concerning for a flail chest, most commonly caused by blunt trauma. Although the diagnosis is made clinically with a paradoxical inward motion of the chest wall during inspiration, it is supported by imaging studies demonstrating two or more consecutive ribs broken at two or more sites. The primary morbidity related to flail chest is the frequent underlying *pulmonary contusion* that accompanies it and compromises adequate respiration. Oftentimes, this does not manifest until 12–24 h when the pulmonary contusion “blossoms.” Furthermore, severe pain may also affect respiration. Pain control is a crucial component of the management of patients with rib fractures. However, always start with the ABCs of trauma. The best course of management for the above patient (given the marked tachypnea and flail chest) is to first ensure an airway with endotracheal intubation. This can be followed by two large bore IVs and fluids (A). Blood products may be needed if he does not respond to fluids and continues to remain hemodynamically unstable (D). There is no indication for a needle thoracostomy or chest tube given that the breath sounds are equal (B). Chest tube may be indicated if the patient had a concurrent pneumothorax on subsequent chest x-ray (E).
- ✓ 6. Answer C
Acute carbon monoxide (CO) poisoning affects the organs with the highest oxygen demand first. Patients will present in the early stages with neurologic complaints (e.g., headaches, dizziness, confusion) and cardiac symptoms (e.g., chest pain, arrhythmias). All these patients should be started on 100% oxygen via nonrebreather facemask. CO has nearly 250x more affinity for hemoglobin than oxygen. Thus, the hemoglobin-oxygen dissociation curve shifts to the left and more hemoglobin is bound by CO than it is by oxygen. This decreases both the hemoglobin saturation (of oxygen) and the oxygen content in the blood. The arterial partial pressure of oxygen is not affected in CO poisoning, and so a compensatory increased alveolar ventilation would not be expected (B, E). CO poisoning is not a consumptive or destructive process, and so hemoglobin would not be expected to change (A). Oxidized hemoglobin, also known as *methemoglobin*, has a higher affinity for cyanide, and so patients with cyanide poisoning are oftentimes given nitrates to induce the oxidization of hemoglobin to help bind the cyanide for renal clearance.
- ✓ 7. Answer E
Electrical burns are deceptive as, at the skin level, there may be a relatively minor burn wound. Yet, the electrical current can penetrate deep into the soft tissues, leading to extensive injury to the soft tissues and muscle. Thus, electrical burns are associated with the development of compartment syndrome. The best indication for fasciotomy is in the presence of compartment syndrome. Choice E is the only choice in which there is an *absolute indication* for fasciotomy as the patient has clear evidence of compartment syndrome. Numbness of the first web space is the classic finding of anterior compartment syndrome, as the deep peroneal nerve travels within it, and it supplies sensation to the first web space. Options B, C, and D are relative indications for prophylactic fasciotomy, as they place the patient at increased risk of subsequently developing compartment syndrome. A crush injury by itself is not considered an indication for prophylactic fasciotomy (A).
- ✓ 8. Answer E
The diagnosis of isolated pancreatic injury is often delayed as it is notoriously known to be missed initially on CT. If there is no associated splenic injury to cause bleeding or bowel injury to cause peritonitis, initial physical examination findings may be unremarkable. In addition, a serum amylase level is neither specific nor sensitive for pancreatic injury (A). However, if there is pancreatic duct disruption, the release of enzymes will eventually lead to symptoms as in the patient presented above. Surgery is recommended for such major injuries and may require a distal pancreatectomy. Minor pancreatic injuries without pancreatic duct disruption can be managed nonoperatively. In such cases, ERCP is more sensitive and specific than MRCP for ductal injury (B, D). CT-guided drainage (C) will not address the underlying pancreatic injury and would not be appropriate for this patient.

✓ 9. Answer B

The patient has sustained a blunt injury to the carotid artery as evidenced by a dissection in the left internal carotid artery. Such an injury should be suspected whenever there is high-energy force to the head and/or neck. He is exhibiting evidence of Horner's syndrome (ptosis, meiosis, anhidrosis), as sympathetic nerve fibers can be interrupted with carotid injury. A dissection is a partial-thickness tear in an artery that begins in the intima and extends into the media. It can narrow or occlude the lumen. Most blunt carotid injuries are managed nonoperatively with antiplatelets or subtherapeutic heparin (provided there is no contraindication). Thus, observation alone would be inappropriate for such a patient (E). Since the dissection extends to the base of the skull, it would be impossible to access and repair through a standard neck incision (A). Conservative management using subtherapeutic heparin or aspirin is the most appropriate option and has been shown to reduce or prevent cerebral infarction in patients with blunt carotid injury. Carotid stenting has a risk of causing a stroke and would not be appropriate for a dissection that extends to the base of the skull (C). Thrombolysis is contraindicated in a patient with a carotid dissection and in patients with trauma causing acute vascular injury (D).

✓ 10. Answer C

Immediate exploratory laparotomy is recommended in the majority of patients with a gunshot wound to the abdomen, particularly if the patient is hemodynamically unstable, has evidence of peritonitis, or has bowel evisceration. However, cooperative patients with gunshot wounds to the abdomen that are hemodynamically stable, with no evidence of peritonitis, are candidates for nonoperative management. They should be evaluated further for injuries requiring surgical repair with an abdominal CT scan. This approach may avoid an unnecessary exploratory laparotomy that carries significant morbidity (B). CT scan should be done even for patients with wounds that appear to only be superficial. If the CT scan is normal, the patient can be managed with serial physical exams and serial laboratory exams (e.g., white blood count) (A). NG tube can help identify gastric injuries, while rectal examination can help identify rectal or colon penetration by the bullet. Though occasionally utilized for penetrating trauma, DPL and FAST are more appropriate for blunt trauma (D–E).

✓ 11. Answer A

It is important to note that acute limb ischemia (in this instance due to embolization of atrial thrombus secondary to atrial fibrillation), followed by reperfusion, is a well-recognized risk for the subsequent development of compartment syndrome. Ischemia/reperfusion results in an increase in vascular permeability to plasma proteins and progressive interstitial edema. This leads to an increase in interstitial pressure. When interstitial pressure exceeds capillary perfusion pressure, muscle ischemia and necrosis ensue. It is important to note that palpable pulses do not rule out compartment syndrome. Treatment is an emergent four-compartment fasciotomy. The lymph system is not involved in the development of acute compartment syndrome (E). A recurrent embolus would not be expected to present with a swollen leg and palpable distal pulses (B). DVT can present with calf tenderness that is worsened with passive extension (Homan sign) (C). However, the temporal relation to his presenting problem and the physical exam findings are more supportive for compartment syndrome. Atherosclerotic plaque would be expected in a patient presenting with claudication secondary to peripheral arterial disease (D).

✓ 12. Answer D

Infections in burn patients can be problematic for multiple reasons. It may delay wound healing, encourages scarring, and can result in bacteremia which may lead to sepsis. *Pseudomonas aeruginosa* is a gram-negative bacillus and is considered to be the most common cause of infections in burn patients. Methicillin-resistant *Staphylococcus aureus* is also commonly seen in burn patients and difficult to treat due to a large number of virulence factors. *Klebsiella* is also commonly seen in burn wounds.

Streptococcus pyogenes is more of a concern in pediatric burn patients because they may have colonization of *Streptococcus pyogenes* in their oropharynx (B). *Streptococcus agalactiae* is not an organism thought to infect burn patients (C). This organism can colonize the genitourinary tract and be transmitted to the neonate during birth which may result in bacteremia, pneumonia, or meningitis. Fungal infections tend to occur in burn patients during the later stages of recovery because by this time the majority of bacteria have been eliminated by the use of antibiotics. The most common cause of fungal infection in burn patients is by *Candida albicans* (E).

✓ 13. Answer B

Duodenal injury following blunt abdominal trauma is rare. When it does occur, it is usually accompanied by other abdominal injuries. Isolated duodenal injuries are even more uncommon. In children, they have classically been reported following a direct blow to the epigastrium such as a bicycle handlebar injury. The retroperitoneal location of some portions of the duodenum may lead to a delay in diagnosis, as enteric contents spilling from the injury may not cause peritonitis. Contrast-enhanced CT scan of the abdomen can help confirm the diagnosis by detecting extravasation of oral contrast, the presence of retroperitoneal air, or a paraduodenal hematoma. Some duodenal injuries can be managed nonoperatively. Specifically, a duodenal wall hematoma, without contrast extravasation, does not require surgery. On the other hand, the presence of contrast extravasation confirms a full-thickness injury that mandates exploratory laparotomy. Depending on the extent of injury, primary repair can be performed. Because of the close relationship of the duodenum to the pancreas and the bile duct, resection of the duodenum is often not possible. Upper endoscopy would be contraindicated in the presence of bowel perforation (D). CT-guided drainage will not address the underlying duodenal injury and would not be appropriate for this patient (E). Laparoscopy would not likely be able to adequately assess and repair the duodenal injury (A).

✓ 14. Answer C

This patient has evidence of compartment syndrome that has led to muscle necrosis as evidenced by high creatine kinase and hyperkalemia (peaked T-waves). Though compartment syndrome is mostly thought of as caused by severe bleeding after trauma, there are many other causes. In this case, it occurred secondary to prolonged compression of the forearm muscles due to his alcohol and drug binge. This resulted in ischemia, followed by reperfusion, and then swelling and death of the muscles. An alcohol binge can also lead to *Saturday night palsy*, a colloquial term referring to radial neuropathy from falling asleep with one's arm hanging over a park bench (compressing the spiral groove which houses part of the radial nerve). Hyperkalemia is a known complication of muscle necrosis from compartment syndrome and, if left untreated, can result in fatal arrhythmias. Although all the options listed (A–B, D–E) are appropriate management options for hyperkalemia, calcium gluconate should be administered *first* to stabilize cardiac myocytes and prevent further damage, particularly because the electrolyte imbalance has already begun to affect the heart (e.g., peaked T-waves).

✓ 15. Answer B

The key to the diagnosis is the history of trauma combined with the chest x-ray. On initial inspection, the chest x-ray could be confused with a hemothorax or pneumonia (D–E). However, the presence of multiple air pockets within the left lung field indicates that there are loops of bowel in the left chest, likely due to a traumatic left-sided diaphragmatic hernia. Traumatic diaphragmatic hernia (TDH) can occur following blunt abdominal trauma secondary to a sudden increase in intra-abdominal pressure. Diagnosis is frequently delayed since patients may be asymptomatic immediately following the traumatic episode. The stomach and colon are the most frequently herniated structures. Patients with TDH can present with both GI and respiratory symptoms. Gastroenteritis is unlikely to present with an increased respiratory rate or an abnormal chest x-ray (A). Following blunt trauma, patients can very rarely present with a delayed

splenic rupture, and this could cause a reactive left pleural effusion. However, once again, this would not cause loops of the bowel in the chest (C).

✓ 16. Answer A

This patient has likely sustained damage to several structures of zone-1 of the neck. The first steps in management are always ABC. Given that there is an expanding hematoma and she is having difficulty speaking, there is concern that her airway is compromised, so she should be intubated. Since the apices of the lungs are contained within zone 1 of the neck, and she has absent breath sounds, she likely has a pneumothorax and will also need a chest tube (B). Duplex ultrasound of the carotid is not necessary since there is a hard sign of vascular injury (C). The patient requires operative repair, but the airway should be protected first (D). This patient may have sustained esophageal injury that will require repair as well, but esophagoscopy should not be performed since she has a hard sign of vascular injury (E).

✓ 17. Answer A

This patient has a penetrating abdominal wound which is concerning for an intraperitoneal injury. Immediate exploratory laparotomy is recommended in patients with a penetrating injury to the abdomen if the patient is hemodynamically unstable, has evidence of peritonitis, has bowel evisceration, or is uncooperative (e.g., intoxicated). Further workup can be considered for patients that are hemodynamically stable, with no evidence of peritonitis (B–E).

✓ 18. Answer C

The muscle is the *first structure* to be affected by ischemic changes in acute limb ischemia, and since it is the primary mass of the tissue in the extremity, the extent and duration of muscle damage are the most critical aspects of limb reperfusion syndrome and subsequent compartment syndrome. The muscle can be tolerant of ischemia for up to 4 hours. Irreversible nerve damage occurs after 8 hours of ischemia (B). Fat changes remain reversible for up to 13 h and the skin up to 24 h, while the bone damage does not typically occur until after 4 days of ischemia (A, D–E).

✓ 19. Answer D

A dislocated limb has the potential of compromising arterial blood flow. As such prompt reduction is essential. However, prior to reduction, the first step is to obtain a plain film of the limb to confirm the dislocation and to rule out associated fractures. Following reduction, a postreduction film is needed to confirm proper alignment. Fasciotomy would be indicated if there is concern for compartment syndrome (pain in calf muscles on passive motion, tense swelling, paresthesias); however, reduction of a dislocated knee would still take priority (A). CT angiography would be performed after reduction if there is concern for arterial injury (ankle-brachial index <0.9) (B). Heparinization would be initiated after limb ischemia is diagnosed (e.g., cold, pulseless limb) (C). MRI of the knee is seldom indicated in the acute setting for knee injuries (E).

✓ 20. Answer B

Patients with blunt chest trauma that present with persistent hypotension, tachycardia, and elevated jugular venous pressure (e.g., distended neck veins) should be suspected of having an injury to the heart. Furthermore, this patient had a drop ≥ 10 mmHg in systolic blood pressure during inspiration (*pulsus paradoxus*) which supports a diagnosis of cardiac tamponade. Although cardiac tamponade classically causes a globular appearance of the heart on chest x-ray, the cardiac silhouette is *frequently normal*. A lung contusion would cause respiratory distress but not features of tamponade (C). An aortic transection presents with a wide mediastinum and would not cause neck vein distention (A). Tension pneumothorax may have distended neck veins, but the collapsed lung would be apparent on chest x-ray combined with tra-

cheal deviation (D). Diaphragmatic injury can occur following blunt abdominal trauma and often present with GI and respiratory complaints though they may initially be asymptomatic (E).

✓ 21. Answer A

Hypotension after blunt trauma should be considered due to hemorrhage until proven otherwise. Head injury should not be considered the source of hypotension. The most likely sources of bleeding are the abdomen, pelvis, and chest. However, major chest bleeding has been ruled out by the negative chest x-ray. In the stable patient, an abdominal CT is the best test to rule out bleeding (E). However, the patient's hemodynamic instability precludes such a study. FAST scan is the test of choice in the unstable patient, but its utility is often limited in obese patients because of poor image quality. In equivocal cases, the next best choice is to perform a DPL to detect free fluid in the peritoneum, which would be an indication for exploratory laparotomy. This is likely the only clinical indication in the modern era where DPL would be appropriate as it allows for a determination of the source of bleeding. Proceeding directly to exploratory laparotomy would be appropriate if the patient manifested peritoneal signs (C). However, if the source of his bleeding was from the pelvis, an exploratory laparotomy may decompress this and result in free hemorrhage from the pelvis into the peritoneum. The appropriate management for an unstable patient with bleeding in the pelvis is to perform pelvic packing. Additionally, his altered mental status precludes a proper physical examination. If the DPL was negative, one would then pursue pelvic angiography to definitively rule out pelvic bleeding (B). Given the GCS of 10, a head CT is indicated, but this would not take precedence over identifying the source of hemorrhagic shock first (D).

✓ 22. Answer C

The patient is displaying evidence of neurogenic shock with hypotension and an *inappropriately* normal heart rate. Neurogenic shock may also present with bradycardia and is associated with a high cervical spinal cord injury (not lumbar spine injury (E)). Priapism (a sustained erection due to unopposed parasympathetic tone) is often a presenting sign of acute spinal cord injury. Neurogenic shock would be expected to present with a normal/high cardiac output, decreased SVR, and sympathetic blockade (A–B, D). Treatment is with intravenous fluids first and, if needed, pressor support (typically norepinephrine).

✓ 23. Answer B

This patient has a dirty wound but has likely had all three tetanus vaccinations. The correct treatment is tetanus vaccination only (A, C). Antibiotics are not indicated since the patient is not infected (E). Since this is a dirty wound, primary closure may not be attempted in this case, and the wound may be packed instead (D).

✓ 24. Answer C

Children with supracondylar fractures are at risk for acute compartment syndrome. There are three mechanisms as to why this occurs: (1) the fracture is often associated with an unrecognized brachial artery injury that leads to ischemia in the compartments of the arm; (2) if the subsequent cast is placed too tightly, this may contribute to compartment syndrome; and (3) initial bleeding and muscle damage/edema cause high pressures in the compartments of the arm leading to compartment syndrome. Compartment syndrome presents with the "six Ps": pain, pallor, paresthesias, paralysis, poikilothermia, and pulselessness (late sign). *Volkmann's contracture* is the manifestation of unrecognized and untreated compartment syndrome. This occurs because prolonged ischemia can lead to muscle death and subsequent fibrotic changes within the tissue. Volkmann's contracture presents with a tense, painful, weak, and shortened forearm with a claw-like deformity of the hand. Nerve entrapment is more likely to

present acutely after the injury and will have deficits consistent with the distribution of a particular nerve (A). Suppurative tenosynovitis is characterized by the four cardinal signs (Kanavel signs): flexor tendon sheath tenderness, fusiform swelling (sausage-shaped digits), pain with passive extension, and a semi-flexed posture of the involved digit (B). Complex regional pain syndrome is a poorly understood phenomenon that occurs in patients that have had a crushing or soft tissue injury, typically to the distal extremities (D). They can present within days or months with intermittent pain, difficulty using the extremity, neglect-like symptoms, and rapid fatigability. An improperly reduced fracture would have been recognized earlier and corrected and would be unlikely to result in the deficits seen in this patient.

✓ 25. Answer E

Cutaneous squamous cell carcinoma arising from a chronic non-healing wound (such as a burn) is known as *Marjolin's ulcer*. Although all the answer choices are considered independent risk factors for skin cancer, chronic inflammation is the most important contributing factor in Marjolin's ulcer and can be seen in burn wounds, scars, chronic ulcers, or sinus tracts (A–D). Carcinoma develops on average 20–30 years after the original burn. All chronic wounds that fail to heal after a long period should undergo a skin biopsy to rule out malignancy.

✓ 26. Answer D

The FAST scan is a bedside ultrasound that is used to detect free fluid in the peritoneal cavity, around the pericardium, and in the thorax. The four areas of focus in a FAST exam are the hepatorenal space, perisplenic space, pouch of Douglas/rectovesical pouch, and pericardial space (C, E). FAST exam cannot distinguish blood from ascites and/or enteric content, is unable to detect retroperitoneal bleeds (from, for instance, a renal laceration with perinephric fluid), and is oftentimes limited by obesity. FAST exam will be able to detect bowel perforation if there is free fluid and only if the bowel is within the peritoneum (so would miss injuries to parts of the duodenum, posterior walls of cecum, sigmoid). For detecting pericardial effusion, the sensitivity approaches nearly 100% (A). Although bilateral pneumothoraces may limit comparison of sides, a single pneumothorax has a sensitivity of 95% and specificity approaching 100% (B).

✓ 27. Answer C

Penetrating neck trauma may result in injury to major blood vessels, the pharynx, esophagus, trachea, and/or cervical spine. Immediate surgical exploration would be indicated if there were hard signs of vascular injury such as a pulsatile bleeding from the wound or rapidly expanding hematoma (the latter only after intubation first to prevent airway compression) (A, D). In the absence of hard signs of vascular injury, immediate surgical exploration is not necessary. Since physical examination is unreliable in terms of ruling out major injury, further imaging with CT angiogram should be obtained. CT angiogram has largely replaced formal angiography which was once considered the gold standard (E). Formal angiogram is invasive (requires a femoral artery catheterization), time-consuming, and costly and is only useful to rule out arterial injuries. Wound closure would only be appropriate for injuries that *do not penetrate* the platysma (B).

✓ 28. Answer B

In a patient presenting with hypotension, distended neck veins, and muffled heart sounds (Beck's triad) following a stab wound to the chest, the most likely diagnosis is cardiac tamponade. The first sign in cardiac tamponade is impaired diastolic filling, which compromises cardiac output, and ultimately results in hypotension and distended neck veins (E). Electrical alternans is characterized by varying alterations in the amplitude of the QRS complex between beats (A). It can occur in various other conditions and is not always present in patients with cardiac tamponade. Radiographic images are often negative initially, but some may develop the characteristic "water-bottle" shape later in the course of the disease (C). In patients that have hemorrhage

after trauma (hemorrhagic shock), the left ventricular cavity becomes smaller as the ejection fraction increases above 75% (D).

✓ 29. Answer C

Many worried pregnant patients arrive to the emergency department following minor trauma. Most patients do not have any significant clinical findings. Her nonstress test showed a normal strip. The criteria to discharge pregnant patients following minor trauma include contractions no more than every 10 minutes, no vaginal bleeding, no abdominal pain, and a normal fetal heart tracing. This patient meets the discharge criteria and does not need to be monitored overnight (A). Biophysical profile is indicated in patients with an abnormal nonstress test (B). CT of the abdomen should not routinely be done in a pregnant patient because of the high radiation risk to the fetus (D). Although there have been no ill effects reported from MRI use during pregnancy, there are no indications to warrant MRI use in this patient (E).

✓ 30. Answer B

Do not forget the ABCs of trauma. The airway should always be addressed first in the primary survey. Burn victims are at high risk for respiratory compromise since the supraglottic airway is susceptible to direct thermal injury and does not have the protection afforded to the infraglottic airway via the reflexive closure of vocal cords to intense heat. Circumferential burns of the neck further increase the risk of respiratory compromise by way of inelastic, circumferential eschars that may constrict the airway. Endotracheal intubation should be performed for all burn patients with acute respiratory distress, circumferential neck burns, full-thickness burns of the face or oropharynx, supraglottic edema, and progressive hoarseness, stridor, or wheezing. Broad-spectrum antibiotics are not routinely recommended for the management of burn victims (A). Burn patients are also at risk for severe intravascular collapse and require significant volume replacement with IV fluid resuscitation (C). However, this should be addressed *after* securing the airway. Premature ventricular contractions are usually benign (D). If the patient did not have indications for immediate intubation (circumferential neck burn), bronchoscopy would be indicated in the presence of singed nasal hairs and carbonaceous sputum to determine the presence of thermal damage to the airway (E).

✓ 31. Answer A

High-energy rapid deceleration chest trauma is most commonly caused by a fall from greater than two stories or from a motor vehicle accident (e.g., steering wheel striking the chest). This mechanism of injury is known to cause aortic injuries which may lead to aortic transection and ultimately death. Autopsy studies of aviation accidents demonstrate that more than 30% of deaths are due to aortic transection. Overall, immediate mortality is greater than 70%. The majority of patients die instantly of exsanguination. Of those who survive, 50% will die within 24 h. Patients will present with a widened mediastinum, deviation of the trachea to the right, and left-sided hemothorax on chest radiographs. They may also have fractures of bones (e.g., first rib, sternum, scapula) that are uncommonly broken as high energy is required to break them. The aortic tear is usually at the ligamentum arteriosum, located just distal to the left subclavian take off, as the aortic arch is relatively fixed to that point. CT angiogram can confirm the diagnosis, and definitive management includes operative repair. Although a ruptured spleen can lead to significant blood loss, instant death is highly unlikely (D). The remaining choices can all cause instant death, but they occur in less frequency than thoracic aortic transection with this mechanism of injury (B, E). Abdominal aortic transection is extremely rare following blunt trauma as it is more mobile than the thoracic aorta (C).

Upper Gastrointestinal Bleeding

Brian R. Smith

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Bloody Emesis

Areg Grigorian, Viktor Gabriel, Christian de Virgilio, and Brian R. Smith

Case Study

A 50-year-old male presents to the emergency department with a 3-hour history of bloody emesis. He has no such prior history. The vomiting was not preceded by retching. He states that the blood was bright red. He currently feels slightly dizzy. He has no history of alcohol abuse. He has noted intermittent

epigastric pain for the past 2 weeks that is relieved by taking oral antacid pills. On review of systems, the patient notes that he injured his knee a month ago and has been taking ibuprofen daily for pain relief. Physical exam reveals a blood pressure of 100/60 mmHg and a heart rate of 110/minute. There are no

signs of jaundice and the abdomen is flat. No hepatosplenomegaly, caput medusa, or spider veins are appreciated. Laboratory values reveal a hematocrit of 40%. Liver function tests are normal as are INR and PTT. BUN is 36 mg/dL and creatinine is 1.0 mg/dL.

Diagnosis

What Is the Differential Diagnosis for an Upper GI Bleed?

Table 49.1

Diagnosis	Comments
<i>Gastritis</i>	Nausea, bloating, dyspepsia, NSAID use, <i>Helicobacter pylori</i> , alcohol abuse
<i>Gastric ulcer</i>	Epigastric pain with eating, <i>Helicobacter pylori</i> , hematemesis more common than melena
<i>Duodenal ulcer</i>	Epigastric pain with empty stomach relieved 2 hours after eating, possible weight gain, <i>Helicobacter pylori</i> ; melena more common than hematemesis
<i>Erosive esophagitis</i>	Associated with infections (herpes simplex virus, cytomegalovirus, <i>Candida</i>), GERD, and drug ingestion (potassium chloride, NSAID, tetracycline)
<i>Mallory-Weiss tear</i>	History of forceful emesis and/or retching (after alcohol binge); partial tear into mucosa/submucosa, self-limited
<i>Esophageal varices</i>	History of alcohol abuse; stigmata of liver disease, including jaundice, spider angiomas, gynecomastia, ascites, caput medusa, palmar erythema, asterixis, encephalopathy
<i>Gastric cancer</i>	Involuntary weight loss, dysphagia, bloating, early satiety, cachexia
<i>Stress-related mucosal damage (ulcers and gastritis)</i>	Critically ill patients, severe trauma, severe burns (Curling ulcer), increased intracranial pressure (Cushing ulcer), shock, likely due to an inability to maintain integrity of the gastric mucosal barrier
<i>Angiodysplasia</i>	Degeneration of previously healthy small vessels, associated with chronic renal failure, valvular heart disease, CHF
<i>Sinistral/left-sided hypertension</i>	Splenic vein thrombosis after acute pancreatitis leading to large isolated gastric varices at risk for rupture and bleeding

Table 49.1 (Continued)

Diagnosis	Comments
<i>Aortoenteric fistula</i>	Prior aortic surgery with graft eroding into distal duodenum; massive hemorrhage, often with a “herald” bleed
<i>Osler-Weber-Rendu disease</i>	Epistaxis, red nodules, and starry telangiectasias on the lips, nodular angiomas/telangiectasias in the small bowel, migraines

NSAID nonsteroidal anti-inflammatory drug, GERD gastroesophageal reflux disease, CHF congestive heart failure

What Are the Most Likely Diagnoses in This Patient?

With an upper gastrointestinal bleed, assumptions about the source of bleeding cannot be made without performing an endoscopy. That being said, given the absence of stigmata of cirrhosis/portal hypertension, the absence of alcohol abuse, no history of retching, and a history of recent NSAID abuse, the most likely diagnoses are either acute gastritis or peptic ulcer disease. The question stem does not give any antecedent dyspepsia or prior symptoms to suggest a history of gastritis. NSAID use may mask the symptoms of dyspepsia.

History and Physical

What Information Can the Color and Texture of Stool or Emesis Provide?

The color and texture of stool or emesis (Table 49.2) can provide clues to the location of the GI bleed. Such information is vital, as it may influence the workup and management. Iron in the red blood cells, when exposed to gastric acid, becomes oxidized, resulting in a coffee-ground appearance. This oxidized iron can also be excreted in the stool, producing a tarry, blackened stool known as *melena*. Coffee-ground emesis and melena are both classic signs of upper GI bleeding. Ninety percent of melena comes from an upper GI source. Bright red blood or maroon-colored stools, also known as *hematochezia*, are more suggestive of bleeding in the lower GI tract (colon). Rarely, bright red blood per rectum is the result of massive bleeding from the upper GI tract, as large volumes of blood act as a cathartic.

Table 49.2 Color and texture of stool and emesis

Emesis or stool	Likely location of lesion
Bright red bloody emesis	UGI (moderate to severe)
Coffee-ground emesis	UGI (more limited)
Black, tarry, foul-smelling stool (<i>melen</i>)	UGI (probable), LGI (possible)
Bright red bloody stool (<i>hematochezia</i>)	UGI (possible), LGI (probable)
Maroon-colored stool	UGI (possible), LGI (probable)

UGI upper gastrointestinal, LGI lower gastrointestinal

What Variables Adversely Affect Prognosis in a Patient with an Upper GI Bleed?

- Increasing age (>65 years old)
- Altered mental status
- Albumin less than 3.0 g/dL
- INR greater than 1.5
- Shock on presentation (systolic blood pressure <90 mmHg)

Pathophysiology

What Are Esophageal Varices?

Esophageal varices are dilated, tortuous veins located in the submucosa of the distal third of the esophagus that form as a result of portal hypertension causing back pressure in vessels that have a systemic connection. Given their size, high pressure, and superficial location, they are highly prone to erode and cause life-threatening bleeding into the lumen of the esophagus. The primary venous drainage of the esophagus is via the esophageal veins that empty into the superior vena cava. However, distal veins within the submucosa empty into the left gastric vein (also known as the coronary vein), which normally drains into the portal vein. In the presence of cirrhosis and impeded portal flow through the liver, the portal vein has much more difficulty draining its blood into the scarred liver. Blood is forced to flow in a retrograde direction, under high pressure, toward the tributaries of the portal vein, leading to varices.

What Are the Differences Between Acute and Chronic Gastritis?

Acute gastritis is an *erosive*, superficial inflammation in the lining of the stomach secondary to the dysfunction of

Table 49.3 Acute versus chronic gastritis

	Acute gastritis	Chronic gastritis
<i>Erosive</i>	Yes	No
<i>Etiology</i>	NSAID abuse, alcohol, steroids, uremia	Pernicious anemia, <i>H. pylori</i> infection
<i>Pathogenesis</i>	Decreased integrity of mucosal barrier	Inflammation related to autoantibodies or <i>H. pylori</i> infection

mucosal defenses. These defense mechanisms include the production of prostaglandins, bicarbonate, and somatostatin. All three reduce the inflammatory effects that gastric acid can have on the gastric mucosa. Increased hydrochloric acid secretion does not play a primary role, but low doses of alcohol have been shown to cause increased acid secretion (high doses do not) which may exacerbate erosions. NSAIDs, which are COX-1 and COX-2 inhibitors, reduce the production of prostaglandins and their protective mechanisms on the stomach lining. Consumption of corrosive materials (e.g., household cleaners, pesticides, gasoline, cosmetics) can also lead to acute gastritis.

Chronic (atrophic) gastritis is a *nonerosive* inflammation of the gastric mucosa (Table 49.3). Type A or fundus-dominant chronic gastritis is associated with pernicious anemia in which the body produces autoantibodies to parietal cells leading to megaloblastic anemia and vitamin B12 deficiency. Type B or antral-dominant chronic gastritis is the most common form and is frequently caused by a *Helicobacter pylori* infection leading to peptic ulcer disease and an increased risk of gastric cancer and mucosa-associated lymphoid tissue (MALT) lymphoma.

What Is Dieulafoy's Lesion?

Dieulafoy's lesion is a rare cause of acute upper GI bleed. This is a congenital dilated submucosal tortuous artery, often located on the lesser curvature of the stomach that erodes the gastric epithelium in the absence of a primary ulcer and is thus exposed to gastric secretions that may lead to massive upper GI hemorrhage. The classic finding on endoscopy is a small, pinpoint defect in the normal-appearing surrounding gastric mucosa with a visible, raised, large vessel that erodes through the mucosa. These lesions are identified endoscopically (if bleeding) and described as a visible vessel without an underlying ulcer present.

What Are the Important Anatomic Correlations for Peptic Ulcer Disease?

The branches of the celiac trunk (■ Table 49.4) may be subject to erosion leading to severe hemorrhage if an ulcer penetrates through the gastrointestinal mucosa and into the vessel.

Workup

Why Might the Hemoglobin/Hematocrit Be Normal in Spite of a Major GI Bleed?

It is important to recognize that the hematocrit is a poor indicator of the severity of acute blood loss. Since the patient is losing whole blood, plasma and red cell volume decrease in the same proportion. As such, the hematocrit may not change at all initially, potentially misleading the clinician. A decrease in hematocrit may not reflect until 12–24 hours after an acute bleed, when the kidney begins to conserve sodium and water. Over time, the patient's hemoglobin will decrease further as fluid is administered with initial resuscitation. However, in a patient with significant bleeding, signs of hypovolemic shock will become apparent earlier. Initial signs of significant blood loss include tachycardia, low urine output, and a narrowed pulse pressure. A thorough knowledge of the stages of shock can provide insight into a patient's status.

Watch Out

A patient's blood pressure may not drop until they have lost 30–40% of their blood volume. By this time, they are in significant shock and are at risk of developing end-organ damage secondary to hypoperfusion.

What Happens to the BUN/Creatinine Ratio During an Upper GI Bleed (UGIB)?

The BUN/creatinine ratio *increases*. In the absence of renal insufficiency, a decreased hemoglobin/hematocrit combined

with a BUN/creatinine ratio greater than 36 (normal <20) suggests an UGIB. This increase is a result of absorption of degraded blood products (protein) during intestinal transit and prerenal azotemia secondary to hypovolemia. BUN/creatinine ratio correlates positively with the likelihood of an UGIB, and isolated increases in BUN can be a subtle indicator of an UGIB.

What Part of the GI Tract Is Considered an UGIB?

From the oropharynx to the distal duodenum (where it crosses the ligament of Treitz), which marks the transition from the retroperitoneal duodenum to the intraperitoneal jejunum, bleeding distal to the ligament of Treitz is considered a lower GI bleed.

If a Patient Presents with Bloody Emesis and Bright Red Blood per Rectum, Is It an Upper or a Lower GI Bleed?

Bright red blood per rectum is usually due to a lower GI bleed (LGIB). However, massive UGI bleeding may cause such a rapid transit of the blood through the GI tract that it does not have time to be subjected to digestive enzymes, resulting in bright red blood per rectum. These patients typically have a significant amount of blood loss, enough to cause hypotension.

What Is the Difference Between Obscure and Occult GI Bleeding?

Occult GI bleed is one that is not known to the patient. It is discovered by either fecal occult blood testing or by noting a microcytic iron deficiency anemia on blood testing. The majority of causes of both upper and lower GI bleeding can present as occult bleeding. *Obscure GI bleeding* is obvious bleeding that is known to the patient, but the source of the bleed, which tends to be recurrent, is hard to identify despite endoscopy. Obscure bleeding tends to arise from pathology in the small bowel and is difficult to visualize with either upper or lower endoscopy, as routine endoscopy generally cannot visualize the small intestine. Only enteroscopy, or push endoscopy, performed by advanced gastroenterologists, can occasionally visualize small intestinal pathology from within the lumen. More recently it has been proposed that the term “obscure” GI bleeding be used only when in addition to upper and lower endoscopy, investigation of the small bowel does not reveal the source of bleeding. Etiologies for obscure bleeding include small bowel vascular ectasia (most common), small bowel ulcers, lymphoma, leiomyoma, leiomyosarcoma, small bowel varices, Crohns, and tuberculosis.

■ Table 49.4 Bleeding vessels in peptic ulcer disease

Branch of the celiac	Type of ulcer	Location
<i>Splenic artery</i>	Gastric	Posterior wall of the stomach
<i>Left gastric artery</i>	Gastric	Lesser curvature of the stomach/gastric cardia
<i>Gastroduodenal artery (comes off common hepatic artery)</i>	Duodenal	Posterior wall of the first portion of duodenum (D1)

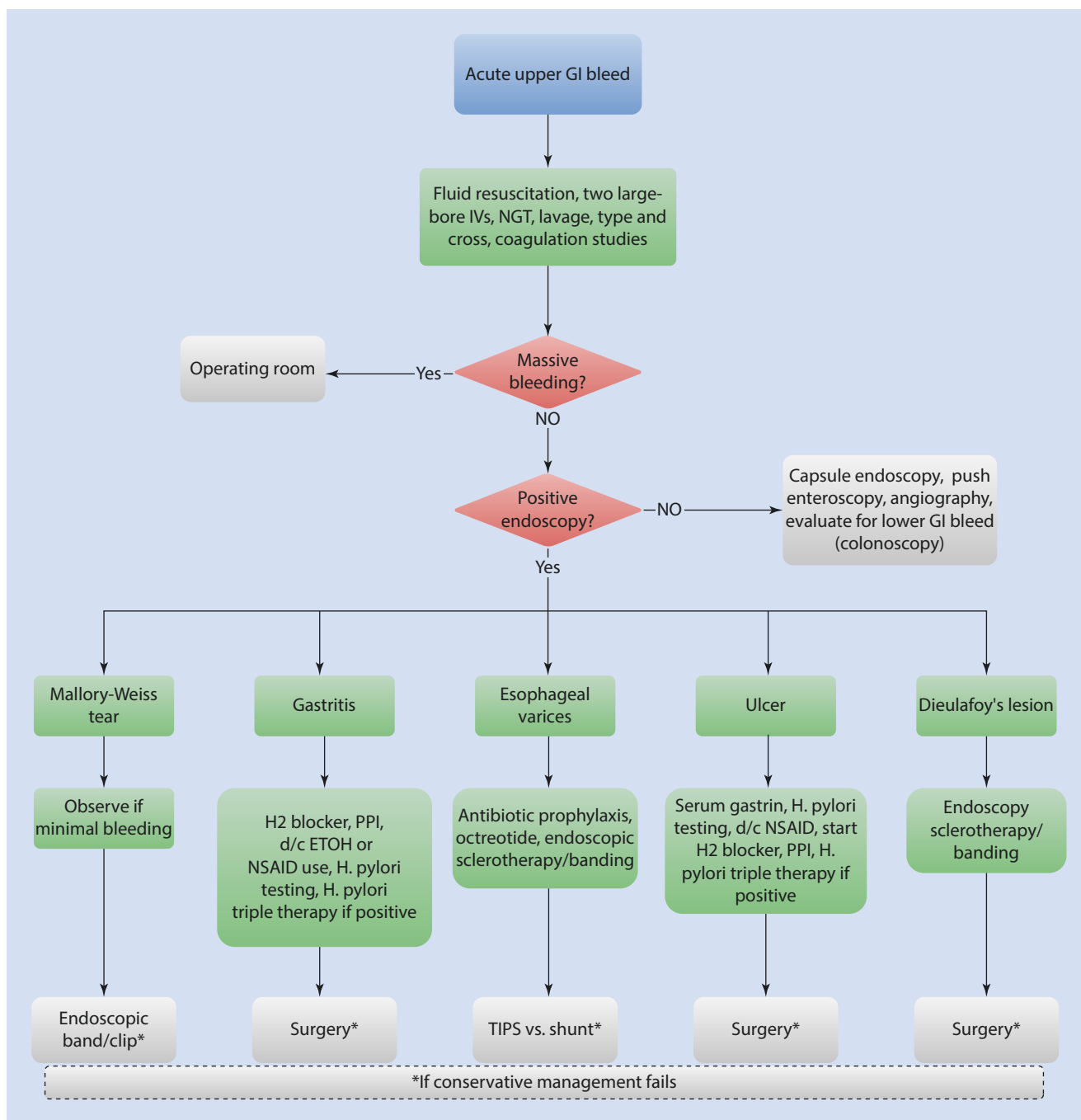


Fig. 49.1 Management algorithm of UGIB

What Is a Common Cause of Obscure GI Bleeding and/or Anemia Unique to Patients with a Hiatal Hernia?

In patients with obscure GI bleeding who have large hiatal hernias and all other sources have been ruled out, repair of the hiatal hernia with subsequent resolution of the anemia would suggest a Cameron's ulcer. This is a gastric mucosal ulceration in which the herniated stomach slides up and down across the diaphragm. The ulcer heals quickly after hernia repair and is rarely visualized preoperatively on endoscopy.

Management

What Are the First Steps in the Management of This Patient?

The first step in evaluation of an UGIB involves assessment of hemodynamic stability and fluid resuscitation (Fig. 49.1). All patients with hemodynamic instability, manifested by hypotension, tachycardia, or active bleeding, should receive two large-bore IV lines and a nasogastric tube (NGT) and be typed and crossed for blood.

Adequate resuscitation and stabilization are essential prior to upper endoscopy, which will determine the source of bleeding. The patient should be admitted to a monitored setting. If the patient is unstable, they should be admitted to the ICU.

Watch Out

If a patient has massive ongoing UGIB, the first step is to secure the airway to prevent aspiration, followed by fluid resuscitation.

What Is the Role of Placing an NG Tube?

NG tube placement has been used to help differentiate between upper and lower GI bleeding. It has been used in workup of patients presenting with a LGIB (since the most common cause of LGIB is UGIB). If NGT lavage returns blood or coffee grounds, the patient has an UGIB. If clear, non-bilious fluid is returned, the source of bleeding is less likely to be proximal to the pylorus of the stomach, but this is considered an *inadequate* lavage until bilious fluid is returned and so an UGIB is still possible. If bilious fluid is returned with no blood, the upper GI tract is unlikely to be the source of bleeding, and more likely to be distal to the ligament of Treitz. However, recent studies indicate that NG lavage is less reliable, particularly if the patient does not have an active bleed, and as such is being replaced with proceeding directly to upper endoscopy. Early upper GI endoscopy (first 24 hours of hospitalization) has been shown to decrease hospital stay, need for surgery, and mortality. It is the most accurate tool for localizing the source of an UGIB.

Watch Out

Do not place an NG tube in a patient with suspected esophageal varices, as the tube may cause injury and more bleeding.

What Is the Difference Between a “Type and Screen” and a “Type and Cross”? Which One Is More Appropriate in This Setting?

Type and screen is requested in circumstances that are not likely to require a blood transfusion, such as elective surgery.

Typing determines ABO and Rh status. Screening involves identifying the presence of alloantibodies in the recipient's blood that may react with donor blood. A positive screen warrants an antibody panel because not all alloantibodies lead to clinically significant reactions. *Type and cross* is utilized when the likelihood of actually needing blood is high, as in the patient described above. In a crossmatch, the recipient blood is tested against donor packed cells to determine if there is a clinically significant response to any antigens on the donor's cells.

What if the Patient Needs Blood Immediately?

In emergent cases, if the patient is exsanguinating and time constraints preclude a type and cross (typically a 30–45 minute process), O-negative blood can be administered. Type O blood is the universal donor because it does not contain A or B antigens, so the recipient will not mount an immune response to it.

How Should the Bed Be Positioned in a Patient Who Is Vomiting Blood?

Provided that there are no contraindications (ongoing hypotension), it is recommended to elevate the head of the bed to an angle of 30° to prevent aspiration. Nevertheless, studies looking at the efficacy of the reverse Trendelenburg position in minimizing aspiration are lacking. If the patient is at high risk of aspiration, or if the patient's mental status is altered, one may consider intubating the patient electively to protect the airway.

Following Resuscitation, What Is the Next Step in the Management?

Any coagulopathy should be aggressively corrected with blood products, including prothrombin complex concentrate if the INR is elevated and platelets for severe thrombocytopenia ($<50,000/\text{mm}^3$). If the patient is taking any anticoagulants, they should be actively reversed. The majority of patients with an UGIB are typically started on an intravenous proton pump inhibitor (PPI). Pantoprazole, lansoprazole, and esomeprazole are the only intravenous formulations available in the United States. A continuous infusion of PPI is not superior to IV push administration. Similarly, there is no difference in the use of high or low-dose PPI.

In What Setting Should the Patient with an UGI Bleed Be Managed?

Unstable patients with an UGI bleed have a high mortality and should be managed in the ICU. Blood volume should be maintained using blood products and intravenous fluids. The patient will need continuous monitoring, which may include a central venous line for central venous pressure monitoring, an arterial line to continuously monitor blood pressure, and an indwelling Foley catheter to monitor urine output.

Following Stabilization, What Is the Next Step in the Management? What Is the Optimal Timing?

Gastroenterology should be consulted to perform early upper endoscopy as the next step. It is both diagnostic and often therapeutic. Ideally it should be performed within 24 hours of admission. Oral erythromycin can be administered prior to endoscopy as it helps clear the stomach of blood via its prokinetic effects.

What if Upper Endoscopy Fails to Show the Source of a GI Bleed, What Other Imaging Might Be Useful?

When endoscopy fails to detect the source of bleeding, the patient has what is termed an obscure bleed. Colonoscopy can be utilized for patients with hematochezia and negative upper endoscopy. The next step depends on the severity of the bleeding. CT angiography has shown promise in identifying bleeding. Formal, angiography is recommended if the bleeding is ongoing as it allows for simultaneous therapeutic intervention (embolization of bleeding vessels). If bleeding is intermittent or minor, capsule video endoscopy and push enteroscopy are recommended. A technetium-99m-labeled red blood cell (tagged RBC) scan is more helpful for lower GI bleeding. It has a high sensitivity; however, it is not specific and has trouble locating the exact location of small bowel bleeding. Tagged RBC scanning can detect slower bleeds (0.5 cc/min), while angiography will only detect more rapid bleeding (rate of 1 cc/min).

In the Absence of Varices, What Are the Therapeutic Endoscopic Options for Treating an UGI Bleed?

Numerous endoscopic techniques are utilized to stop bleeding in the stomach and duodenum including injection of epinephrine, bipolar electrocautery, heater probe coagulation, argon plasma coagulator, laser photocoagulation, application of hemostatic materials, and use of endoscopic clips.

What Are the Indications for Surgery in a Patient with an Upper GI Bleed?

- Failure of endoscopic therapy (usually after two attempts)
- Persistent hemodynamic instability despite aggressive resuscitations
- Cardiovascular disease with predictive poor response to hypotension
- Hemorrhagic shock

What Are the Surgical Options in a Patient with a Bleeding Ulcer that Fails Medical Management?

For bleeding *duodenal* ulcers, the duodenum is opened longitudinally, and the bleeding ulcer on the posterior wall of the duodenum is oversewn in three quadrants, so as to make sure that the bleeding gastroduodenal artery is properly ligated. All patients with bleeding duodenal ulcers should be treated for *H. pylori* postoperatively if they test positive (approximately 90%). Classically, if the patient is stable and if there is a long-standing history of ulcer treatment, an acid-reducing surgery such as truncal vagotomy and pyloroplasty is performed to reduce recurrence. A third option in a stable patient is a highly selective vagotomy (HSV, a tedious and technically demanding operation) which spares the innervation to the antrum and pylorus, thus minimizing the adverse effects on gastric emptying seen with a truncal vagotomy (delayed gastric emptying). Vagotomy works by reducing the stimulation of the parietal cells and the secretion of gastric acid. Acid-reducing surgery is recommended only if the patient has a type II or type III gastric ulcer, as these are associated with increased acid production. Additionally, for gastric ulcers, the optimal treatment is to excise part of the stomach to include the ulcer, as there is a higher risk of underlying malignancy with gastric ulcers. Approximately 80% of gastric ulcers will test positive for *H. pylori*.

Watch Out

Over the past few decades, there has been a declining need for surgery to treat peptic ulcer disease as a result of the widespread eradication of *H. pylori* and the use of proton pump inhibitors, as well as the success of endoscopic hemostasis. The most common reason for surgical intervention in benign gastric ulcers is failure of the ulcer to completely heal after a 6-month trial of medical or endoscopic therapy, often resulting in obstruction or chronic bleeding.

Special Management Circumstances

If an Ulcer or Gastritis Is Found on Endoscopy, What Additional Studies/Therapies Are Recommended?

H. pylori infection is present in the majority of uncomplicated gastric or duodenal ulcers. Leaving this untreated can result in recurrent ulcers which may lead to perforation. In addition, there is an increased risk for the development of lymphoma in the stomach (MALToma, mucosa-associated lymphoid tissue lymphoma) as well as gastric adenocarcinoma as a consequence of long-standing infection. After confirmation of infection with *H. pylori* (see section below), the standard first-line therapy consists of “triple therapy” with a proton pump inhibitor such as omeprazole, along with clarithromycin and amoxicillin. Most patients are treated with triple therapy for 2 weeks.

How Do You Test for *H. pylori* Eradication?

Because of the increasing presence of antibiotic-resistant *H. pylori*, it is recommended to confirm eradication of infection in all patients 4–6 weeks following treatment. The best test is the urea breath test (UBT). The urease produced by *H. pylori* can hydrolyze urea to produce CO₂ and ammonia, which can be traced using a radiolabeled carbon isotope given by mouth to the patient. The patient should be off proton pump inhibitors for 2 weeks prior to the test because it can result in a false negative. The sensitivity and specificity of UBT are approximately 88–95% and 95–100%, respectively. Other options to confirm eradication include stool antigen testing (the most cost-effective option currently) or endoscopy with biopsy. Endoscopy with biopsy is the recommended test after two courses of antibiotics have been attempted. Serologic testing demonstrates prior exposure to *H. pylori* by detecting IgG antibodies but is a poor choice to test for eradication.

How Does the Management of UGI Bleed Differ for Esophageal Varices?

Unlike other causes of UGIBs, variceal bleeding is also managed with short-term antibiotic prophylaxis (decreases infection risk and improves survival). Somatostatin (octreotide) and vasopressin are given systemically to reduce portal blood flow. However, vasopressin causes systemic vasoconstriction and is therefore contraindicated in patients with coronary artery disease. Esophagogastroduodenoscopy (EGD) with endoscopic banding is the best approach to stop the bleeding varices as it causes less injury to the esophagus than sclerotherapy (which is another option). Temporary balloon tamponade is another option. Endoscopy is typically repeated in 48 hours to band any remaining vessels. If combination therapy and repeat endoscopic therapy fail to control bleeding,

transjugular intrahepatic portosystemic shunting (TIPS) may be considered to definitively lower portal pressure.

What Is the Best Way to Prevent Recurrent UGI Bleed from Esophageal Varices?

For esophageal varices, long-term nonselective β -blocker (nadolol or propranolol) use has been shown to decrease the likelihood of rebleeding. β -Blockers are not helpful in the acute setting as they do not stop bleeding.

How Does the Management of UGI Bleeding Differ for a Mallory-Weiss Tear?

Mallory-Weiss tears are linear erosions in the gastroesophageal mucosa and submucosa that result from a sudden increase in intra-abdominal pressure. Precipitating factors include vomiting, retching, straining during defecation, heavy lifting, or violent coughing. The typical patient is middle-aged with a history of binge drinking and retching without blood, prior to the onset of bloody emesis. The bleeding is almost always self-limited, as the erosions heal rapidly. Only in rare cases is sclerosing therapy or electrocautery needed. Surgery is even more rarely required and would consist of oversewing the bleed through a gastrotomy.

What Is the Best Way to Prevent/Treat Stress-Related Mucosal Damage (Stress Ulcers and Stress Gastritis)?

The best way to prevent stress ulcers is by maintaining a gastric pH greater than 5 using intravenous proton pump inhibitors. Once diagnosed, most patients can be treated with an intravenous proton pump inhibitor. However, if further intervention is necessary for resolution, angiographic embolization is the preferred therapeutic approach to decrease vascularity to specific areas of the stomach. This intervention is rarely required.

Why Would Patients Develop Nausea, Dizziness, and Flushing Postgastrectomy?

Patients with bleeding gastric ulcers may require a partial gastrectomy. The most common complication from this surgery is dumping syndrome, which occurs in early and late forms. Early dumping (30 minutes after eating) presents with GI symptoms including nausea, emesis, bloating, and explosive diarrhea, as well as cardiovascular symptoms including diaphoresis, dizziness, and flushing. The etiology for this is related to the release of serotonin, bradykinins, and enteroglucagon. Late dumping occurs 3 hours after eating and presents with symptoms consistent with hypoglycemia

(diaphoresis, confusion, and tachycardia). This is related to a large amount of carbohydrates suddenly entering the duodenum leading to insulin secretion.

Areas Where You Can Get in Trouble

Assuming That UGI Bleeding in an Alcoholic Is Due to Esophageal Varices

Esophageal varices occur as a result of high pressures in the portal system, often secondary to alcohol-induced cirrhosis. Although alcohol is the prevailing cause of portal hypertension, hepatitis B and C are also prominent. However, it is crucial to rule out other etiologies by performing an endoscopy. A Mallory-Weiss tear should be considered if the patient presents with a history of retching prior to bleeding. A careful history should be taken to determine if NSAIDs may have played a role or if the patient has a known history of ulcers.

Sequelae of Ingesting Harmful Liquids

Patients with suicidal ideations or young children can mistakenly ingest harmful household substances. Acidic liquids (e.g., hydrochloric acid) can cause a chemical burn to the esophagus and gastric mucosa and increase risk of ulceration and perforation. Alkaline substances (e.g., liquid detergents, cleaning liquids) are more commonly ingested and produce more widespread and severe injuries. In the acute setting, EGD is used to visualize the extent of esophageal and gastric injury, but the endoscope should not traverse the affected area as this increases risk of perforation. Weeks to months after acidic/alkaline ingestion, patients may develop strictures either in the esophagus or near the pylorus. Esophageal strictures will present with dysphagia, while pyloric strictures will present with symptoms suggestive of gastric outlet obstruction (nausea, emesis, early satiety, bloating, and weight loss).

Area of Controversy

When Should Transfusion Be Given for an Acute UGIB?

Blood transfusion is often necessary for an acute UGIB. There is no single laboratory or diagnostic criterion on which to base blood transfusion decisions. Recent studies suggest that a liberal policy of blood transfusion worsens outcomes and that blood transfusion should be withheld unless the hemoglobin drops below 7 g/dl. Elderly patients and those with compromised cardiac function are at risk for volume overload when given a large volume of blood transfusions. Over-transfusion of patients with variceal hemorrhage can

precipitate rebleeding. However, it is reasonable to maintain higher transfusions thresholds (>9 g/dl) in patients with ongoing bleeding or ones with unstable coronary artery disease.

Summary of Essentials

History and Physical Exam

- Do not forget to ask about alcohol and NSAID use.
- Always inquire about any known *H. pylori* status.
- Look for stigmata of alcoholic cirrhosis.

Pathology/Pathophysiology

- UGIB is proximal to ligament of Treitz.
- About 75% of GI bleeding is from the upper GI tract.
- Most common cause of melena (LGIB) is UGIB.
- An occult bleed is defined by fecal occult blood positivity and/or iron deficiency anemia.
- An obscure bleed is an obvious bleed without a source: think small bowel.

Differential Diagnosis

- Consider stress ulceration in a critically ill ICU patient.
- Consider an aortoenteric fistula if the patient has a history of aortic surgery; work up with endoscopy and CT (gas/stranding around graft).
- Consider Mallory-Weiss tear if bleeding follows forceful vomiting.

Diagnosis

- When it is unclear whether the bleed is upper or lower GI, start with upper endoscopy.
- UGI bleeding can increase BUN/creatinine ratio.

Management

- Start with ABCs (airway, breathing, circulation), two large-bore IVs, and type and cross.
- With a massive bleed, consider intubation to protect the airway.
- Liberal blood transfusion policy not helpful; restrict blood unless the hemoglobin drops below 7 g/dl.
- Start PPI early.
- Triple therapy for *H. pylori* eradication.
- Admit to monitored setting.
- Perform upper endoscopy within 24 hours.

- Most bleeding successfully treated with endoscopic techniques.
- Surgery only if endoscopy fails: duodenal ulcer (open duodenum, three-point ligation of ulcer) and gastric ulcer (excise and close for acute vs distal gastrectomy for chronic history of ulcer disease).
- For variceal patients with cirrhosis, calculate MELD score.

Special Management Situations

- With isolated gastric varices along the greater curve, consider splenic vein thrombosis from prior pancreatitis; splenectomy is curative.
- Gastric varices are more difficult to treat than esophageal varices and do not respond well to banding or sclerotherapy.
- Mallory-Weiss tear: bleeding usually stops spontaneously.

Prevention

- Use proton pump inhibitors in patients on long-term NSAID therapy (e.g., rheumatoid arthritis) to prevent ulcers.

- Propranolol helps prevent recurrent bleeding from esophageal varices; it is not helpful in an acute bleeding episode.

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Severe Epigastric Abdominal Pain

Viktor Gabriel, Sahil Aggarwal, and Brian R. Smith

Case Study

A 61-year-old male with a history of gastroesophageal reflux disease (GERD), hypertension, and diabetes presents to the emergency room complaining of severe abdominal pain. The patient reports epigastric pain on and off for months but with a sudden and severe worsening acutely over the last 8 hours. He states that the chronic pain has been a “gnawing” pain

that comes on after eating. He typically takes antacids for relief. Late last night, the pain became excruciating and he is now having trouble moving. On physical exam, blood pressure is 130/70 mmHg, heart rate is 120/min, and temperature is 39.1 °C. He appears to be in severe distress secondary to pain. His mouth appears dry. Bowel sounds are absent. He has diffuse

tenderness to palpation, with guarding and rebound tenderness. Laboratory values reveal a white blood cell count of 18,000/ μ L (normal 4.1–10.9 $\times 10^3$ / μ L), BUN of 40 mg/dl (7–20 mg/dl), creatinine of 1.8 mg/dl (0.5–1.4 mg/dl), serum amylase of 130 μ /L (30–110 μ /L), and lipase of 60 μ /L (7–60 u/L). An upright chest x-ray demonstrates free air under the right diaphragm.

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Diagnosis

What Is the Differential Diagnosis?

Table 50.1

Diagnosis	History and physical
<i>Acute cholecystitis</i>	Persistent postprandial right upper quadrant (RUQ) pain, radiating to the scapula, positive Murphy's sign; fever
<i>Acute pancreatitis</i>	Severe epigastric pain radiating straight through to the back in a patient with history of cholelithiasis or alcohol abuse
<i>Acute cholangitis</i>	Persistent RUQ pain, fever, jaundice (<i>Charcot's triad</i>)
<i>Perforated gastric or duodenal ulcer</i>	History of peptic ulcer disease (PUD), <i>H. pylori</i> or chronic NSAID use; tachycardia, epigastric abdominal pain radiating to the shoulder; guarding, rigidity, and rebound tenderness suggestive of peritonitis
<i>Diverticulitis</i>	Can present with signs of peritonitis; pain is usually located in the left lower quadrant (LLQ)
<i>Small bowel obstruction</i>	Severe abdominal pain and marked abdominal distention; extensive nausea/vomiting and failure to pass flatus

NSAID nonsteroidal anti-inflammatory drug

What Is the Most Likely Diagnosis?

The free air under the diaphragm indicates that the patient has a perforated viscus. This is supported by evidence of diffuse peritonitis on physical exam. The most common causes of free air under the diaphragm are perforated ulcers and perforated diverticulitis. Given the long-standing history of epigastric pain relieved by antacids, the most likely diagnosis is a perforated peptic ulcer.

History and Physical

What Are the Most Common Symptoms in a Patient with Peptic Ulcer Disease (PUD)? How Might One Distinguish Gastric from Duodenal Ulcers?

The most common presenting symptom and sign are well-localized, non-radiating midepigastric abdominal pain and tenderness, respectively. However, the description and location of the pain can vary and be vague. A comparison of duodenal and gastric ulcers can be seen in Table 50.2. Patients with gastric ulcers often have pain that is brought on 30 minutes after eating (food releases stomach acid). As such they may stop eating and lose weight. Patients with duodenal ulcers report relief of pain with eating (food released bicarbonate in duodenum), so they may gain weight or they may develop pain 2–3 hours postprandially (so they may wake up at night with pain). Other signs and symptoms include nausea, vomiting (more with gastric ulcer), melena, and vomiting of blood (more common with gastric ulcer).

Table 50.2 Types of gastric ulcers

Duodenal ulcer	Gastric ulcer
Increased acid	Normal or low acid
Pain may be relieved by food but may return 3 hours later	Pain exacerbated by food
Wake up at night with pain	No pain at night
May gain weight	May lose weight
Malignancy very rare	Malignancy occasionally seen
If bleeds, usually presents as melena	If bleeds, usually presents as hematemesis

What Is the Typical Presentation for a Perforated Peptic Ulcer?

Patients will classically present with a triad of acute onset of abdominal pain, tachycardia, and abdominal rigidity. They may occasionally complain of shoulder pain secondary to diaphragm irritation (referred pain from the phrenic nerve), right lower quadrant pain secondary to fluid tracking along the right paracolic gutter, as well as abdominal distension and vomiting. Approximately a third of patients will have a known history of PUD, and around 5–10% will present with septic shock. On physical exam, the patient will likely be lying motionless and have peritonitis characterized by exquisite tenderness to palpation, abdominal guarding, and rigidity. Depending on the duration of symptoms, the patient may have evidence of marked hypovolemia secondary to a combination of peritonitis, poor oral intake, and/or vomiting. Laboratory findings may be benign, other than leukocytosis with left shift and elevated BUN/creatinine ratio secondary to hypovolemia. Due to the location of the pain, pancreatitis should be in the differential diagnosis. Amylase and lipase should be ordered and will likely be within normal limits. However, a posterior ulcer can cause elevation of serum amylase secondary to peripancreatic inflammation or spillage of amylase-rich luminal fluid. Late presenting perforated ulcers (>12 hours) may present in septic shock, which may be accompanied by a metabolic acidosis with an elevated lactate. However, the acidosis can be masked by respiratory compensation or by the loss of acid via extensive vomiting.

Pathophysiology

How Common Are Peptic Ulcer Perforations and How Often Do They Result in Death?

PUD is one of the most common gastrointestinal disorders worldwide, but the rate of perforation secondary to PUD has dramatically decreased since the introduction of medical therapy for *Helicobacter pylori* (antibiotics and proton pump inhibitors). However, ulcers continue to be a common cause of perforated viscus as a result of the ongoing use of aspirin and NSAIDs. Gastroduodenal perforations occur in up to 10% of patients with PUD and account for more than 70% of deaths associated with PUD. Duodenal ulcers are more likely to perforate than gastric ulcers.

What Is the Most Common Cause of Peptic Ulcers?

Peptic ulcers are a result of an increase in destructive factors and decrease in protective factors or combination of the two. Destruction of the mucosal barrier results from a variable combination of factors ranging from hypersecretion of hydrochloric acid to hyposecretion of mucosal defense mechanisms,

such as mucus and bicarbonate. *H. pylori* accounts for more than 90% of duodenal ulcers and up to 80% of gastric ulcers. In addition to producing toxic mediators that degrade mucus, *H. pylori* induces a local inflammatory reaction. The inflammatory reaction caused by *H. pylori* invokes a hypersecretion of gastrin which in turn leads to an increase in acid secretion. This leads to the development of antral gastritis. The production of prostaglandins, bicarbonate, and somatostatin has been recognized to decrease in patients with *H. pylori* and normalizes once the bacteria are eradicated.

How Do NSAIDs Lead to Peptic Ulcers?

By inhibiting both COX-1 and COX-2 production, NSAIDs inhibit prostaglandin synthesis, which has a negative impact on mucosal defenses. Prostaglandins stimulate mucin and bicarbonate production by gastric epithelium, reduce the production of acid by acting upon the parietal cells of the stomach, and enhance mucosal blood flow by inducing local vasodilation. The chronic use of NSAIDs results in the unopposed secretion of acid and a reduction in mucosal defense and blood flow.

What Are Some Other Factors That May Lead to the Presence of Peptic Ulcers?

Other factors include smoking, alcohol, steroids, and stress. Cigarette smoking has been found to double the risk of developing PUD compared to nonsmokers. Smoking results in an imbalance between mucosa apoptosis and proliferation. Additionally, cigarette smoke has an inhibitory effect on prostaglandins and mucus production, resulting in a decrease in defense mechanisms. Alcohol damages gastric mucosa and stimulates gastrin secretion. Cushing and Curling stress ulcers occur in head trauma and burn patients, respectively. Gastrin-secreting tumors of the pancreas may also lead to recurrent ulceration as part of Zollinger-Ellison syndrome.

What Are the Different Types of Peptic Ulcers and How Are They Categorized?

Table 50.3

Type	Location	Acid hypersecretion?
I	Lesser curvature (most common)	No
II	Lesser curvature and duodenum	Yes
III	Prepyloric	Yes
IV	Gastric cardia	No
V	Any location in stomach (NSAID use)	No

Watch Out

Only Type II and III gastric ulcers would benefit from an acid-reduction surgery, if one is indicated, as these are the only ones resulting from acid hypersecretion.

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How Does Vomiting Change a Patient's Acid/Base Balance?

Vomiting results in the loss of fluid rich in potassium and hydrochloric acid. The loss of acidic fluid relative to bicarbonate leads to a metabolic alkalosis. If the vomiting continues, the patient will also start losing sodium, and renal perfusion will decrease. This will be sensed by the macula densa cells of the kidneys and result in the activation of the renin-angiotensin-aldosterone system. This results in reabsorption of sodium and water within the renal tubules at the expense of potassium cations. To avoid severe hypokalemia which can lead to fatal arrhythmia, the kidneys begin to secrete hydrogen ions instead of potassium resulting in *paradoxical aciduria* in the context of *contraction alkalosis*.

Workup

How Is the Diagnosis of Perforated PUD Established?

The diagnosis is usually made with clinical examination (peritonitis) and confirmed by radiologic findings. These findings can be masked in obese patients due to extensive subcutaneous fat. In the majority of patients, they will exhibit guarding with palpation and significant muscle rigidity, as well as evidence of a systemic inflammatory response (leukocytosis, tachypnea, fever, tachycardia).

What Laboratory Studies Should Be Sent?

Complete blood count and blood chemistries should be ordered. Blood test abnormalities may include leukocytosis with a left shift, elevated C-reactive protein (CRP), decreased albumin (predicts mortality), and an elevated BUN/creatinine ratio indicating prerenal acute kidney injury secondary to hypovolemia. Amylase and lipase should be obtained to exclude pancreatitis. Liver function tests should also be sent with upper abdominal pain, as patients with choledocholithiasis or cholecystitis often complain of epigastric pain rather than right upper quadrant pain. Serum gastrin level is indicated in patients with recurrent ulcers and may aid in establishing the diagnosis of Zollinger-Ellison syndrome. Patients should also be tested for *H. pylori* infection.

What Additional Diagnostic Studies Are Recommended for a Patient with a Suspected Perforated PUD?

The classic finding on an acute abdominal series or upright chest x-ray is pneumoperitoneum (free air) – a hyperlucent area under one or both hemidiaphragms (although free air under the left diaphragm alone can be difficult to distinguish from the gastric air bubble). However, absence of pneumoperitoneum does not exclude the diagnosis of perforation. Within the elderly population, free intraperitoneal air on plain radiographs is absent in 40% of patients. For posterior gastric ulcers, care must also be taken to evaluate for retroperitoneal air. In this subset of patients, their abdominal exam may not be impressive due to little or no peritoneal soilage despite a significant and potentially life-threatening perforation.

What Is the Role of CT Scan?

If the diagnosis is still in question after initial physical exam, labs, and plain films, a CT scan of the abdomen with oral contrast (gastrografin) will be able to diagnose pneumoperitoneum and confirm the diagnosis of perforation with a diagnostic accuracy of 98%. On occasion the perforation has sealed itself. In this case there may be free air without contrast extravasation. Nonoperative management may be undertaken in select cases with a sealed perforation. The CT would also rule out alternative diagnoses (such as pancreatitis or perforated diverticulitis).

What Is the Role of an Upper GI Study (UGIS)?

With the advent of CT scan, an UGIS is less utilized. However, an UGIS with water-soluble contrast can also confirm the diagnosis. If the CT scan shows no oral contrast extravasation, an UGIS several days later is useful to confirm that the leak has remained sealed off.

Watch Out

It is important to note that if a perforated peptic ulcer is suspected, using barium in an upper GI study is contraindicated as this can cause barium peritonitis. Additionally, an upper endoscopy is a relative contraindication as insufflation of air may exacerbate a perforation.

What Factors Increase Mortality in Perforated PUD?

- Age > 65 years
- Active cancer
- Hyperbilirubinemia
- Delay from perforation to surgery >24 hours
- Hypoalbuminemia
- Elevated creatinine (>2× from baseline)

Management

What Is the Basic Principle of Surgical Treatment for Perforated Peptic Ulcer?

Sepsis has been found to occur in up to 20% of patients with a peptic ulcer perforation; therefore adequate volume resuscitation to provide organ perfusion and careful monitoring within the ICU are necessary. A nasogastric tube should also be placed to decompress the stomach and attempt to decrease the amount of spillage into the abdominal cavity. The patient should also be given IV broad-spectrum antibiotics and antifungals. Antibiotics should cover gram-negatives, anaerobes, mouth flora, and fungi. If the patient is not already on an intravenous PPI, this should also be started as well as triple therapy if *H. pylori* positive (clarithromycin, amoxicillin, or metronidazole and a PPI for 2 weeks).

How Should a Perforated Peptic Ulcer Be Repaired?

For a perforated duodenal ulcer, the hole is repaired with through-and-through sutures at the site of the perforation which are then tied over a pedicled piece of omentum (known as an omental/Graham patch). The omentum produces high levels of tissue factor, leading to fibrin formation to seal GI tract perforations and stop bleeding, and acts as a nidus for an inflammatory reaction. If proper *H. pylori* treatment and antisecretory therapy are given postoperatively to patients with a perforation, primary closure with omental patch is all that is necessary in the vast majority of cases. Prior to our understanding of the role of *H. pylori* in ulcer diathesis, additional surgical procedures to reduce stomach acid secretion were often performed but are now rarely necessary. They are now performed in <10% of cases and are usually performed in patients with large or recurrent ulcers, in patients with ulcers while on antibiotics and antisecretory medications, or in patients where future compliance with medical therapy is a concern. Antisecretion procedures lead to a longer operation and a significantly increased risk of complications. For perforated gastric ulcers, ulcer closure alone is not sufficient. Rather, a biopsy needs to be obtained or a full-thickness primary ulcer excision is needed, as this approach assures a tissue biopsy to rule out malignancy.

Is Conservative (Nonoperative) Management in Perforated PUD Ever Appropriate?

Yes. One may consider a conservative approach if *all* the following criteria are met: (1) it has been less than 12 hours since the onset of symptoms, (2) the patient is hemodynamically stable without peritonitis, (3) the patient is less than 70 years old, (4) the patient does not have a history of failed medical

therapy for a peptic ulcer, (5) the patient has associated comorbidities that make the surgery too high risk, and (6) there is radiologic documentation that the perforation is sealed.

What Are the Principles of Management of Nonoperative Management?

Nasogastric decompression, antibiotics, initiation of a PPI, and close observation have been reported in the literature as a successful alternative to surgery in a specialized group of patients with a perforated ulcer that has already spontaneously sealed (occurs in 40–80% of cases). Conservative therapy is successful in about 70% of patient with a sealed perforation. It affords comparable morbidity and mortality while avoiding an operation and its associated complications. If the patients deteriorates or fails to improve within the first 12 hours of conservative management, then surgery is indicated.

Can Perforated Peptic Ulcers Be Treated Laparoscopically?

Laparoscopic repair is now considered a reasonable initial operative approach for perforated ulcers in appropriately selected patients. While there is no study with adequate power to show that laparoscopic repair offers a mortality benefit over open ulcer repair, there are established advantages of laparoscopic repair, including shorter operative time, less postoperative pain, fewer pulmonary complications, shorter duration of hospital stay, and a reduced rate of wound infections. While there is no consensus as to the best initial approach, laparoscopic repair is reasonable in hemodynamically stable patients with no prior significant abdominal operations, especially for duodenal ulcers. However, laparoscopic repair of peptic ulcer perforations should only be performed by an experienced laparoscopic surgeon.

Summary of Essentials

History and Physical

- Sudden onset severe epigastric pain that becomes diffuse suggestive of perforated viscus
- History of PUD, *H. pylori*, smoking, alcoholism, and chronic steroid or NSAID use
- Abdominal guarding, rigidity, and rebound tenderness

Pathophysiology

- Acid hypersecretion or mucosal defense hyposecretion
- Five types of gastric ulcers
 - Type I ulcers are on the lesser curve of the stomach.
 - Type II ulcers are in the stomach and duodenum.

- Type III ulcers are prepyloric.
- Type IV ulcers are located proximal by the cardia.
- Type V ulcers are anywhere secondary to NSAID use.

- Triple therapy: clarithromycin, amoxicillin, or metronidazole and a PPI for 2 weeks to eradicate *H. pylori*
- Additional acid-reduction surgery rarely needed

Workup

- Acute abdomen with diffuse peritonitis
- Leukocytosis with left shift
- Upright CXR: free air under diaphragm
- CT with oral gastrografen if plain films nondiagnostic

Management

- Duodenal perforation
 - Primary closure with an omental patch
- Gastric perforation
 - Primary closure, biopsy, and omental patch vs. wedge resection and closure
 - Must rule out malignancy

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Weight Loss and Early Satiety

Sahil B. Gambhir and Brian R. Smith

Case Study

A 73-year-old Japanese female presents with complaints of abdominal pain, weight loss, and early satiety. She states that she has been experiencing a “gnawing” pain in the mid-epigastrium. The pain originated 8 months ago, but she attributed it to acid indigestion. She took an over-the-counter proton pump inhibitor (PPI) and some calcium carbonate (Tums), and the pain initially improved. The pain has progres-

sively worsened, and now she is experiencing early satiety. Over the past 4 months, she has lost 25 lbs, is easily fatigued, and unable to perform daily tasks around the house. The patient has a 50 pack-year history of smoking. She denies more than the occasional alcoholic beverage. She moved to the United States 10 years ago. Family history includes her father passing away of “some type of cancer” and “ulcers”

among two of her siblings. Physical exam reveals a cachectic female with tenderness to deep palpation in the mid-epigastrium, with no rebound or guarding. Laboratory findings include a hemoglobin of 8.5 g/dl (normal 12–15 g/dl) and hematocrit of 27% (36–47%) and mean corpuscular volume (MCV) of 65 μm^3 (80–94 μm^3). All other routine lab findings were within normal limits. A fecal occult blood test is positive.

Diagnosis

What Is the Differential Diagnosis for a Patient with Vague Abdominal Pain?

Table 51.1

Diagnosis	Pertinent positives and negatives
<i>Peptic ulcer disease (PUD)</i>	Burning abdominal pain, nausea, vomiting, bloating; history of PPI or H_2 -blocker use; pain presents postprandially and usually self-limited; not likely to have significant weight loss; history of <i>H. pylori</i> and/or chronic NSAID use
<i>Gastroesophageal reflux disease (GERD)</i>	Postprandial abdominal and chest pain (heartburn); bitter taste in the mouth, regurgitation, bloating
<i>Pancreatitis</i>	Midepigastriac pain; significant tenderness to palpation; elevated pancreatic enzymes; history of alcohol abuse or cholelithiasis
<i>Cholelithiasis</i>	Right upper quadrant or midepigastriac pain, often postprandial and intermittent (colicky); associated with fatty foods; may have elevated LFTs; ultrasound positive for stones
<i>Hiatal hernia</i>	Sliding and paraesophageal hernias may cause upper abdominal pain, anemia, and chest pain with or without GERD symptoms; may need immediate surgical intervention if signs of incarceration or strangulation (pain with nausea/vomiting) are present
<i>Gastric outlet obstruction</i>	Persistent nausea/vomiting and abdominal discomfort and bloating, early satiety
<i>Small bowel obstruction</i>	Nausea/vomiting with vague abdominal pain and distention; absent flatus and stool; history of abdominal surgery; most common cause is adhesions from prior surgery
<i>Gastric cancer</i>	Vague abdominal pain or discomfort, involuntary weight loss, early satiety, dysphagia, iron deficiency anemia, cachexia
<i>Colon cancer</i>	Iron deficiency anemia (right colon), change in stool caliber, bright red blood per rectum (left colon)
<i>Pancreatic cancer</i>	Painless jaundice, weight loss, acholic stools, new-onset diabetes

PPI proton pump inhibitor, NSAID nonsteroidal anti-inflammatory drug, LFT liver function test, GERD gastroesophageal reflux disease

What Is the Most Likely Diagnosis?

In an elderly patient with abdominal pain, significant weight loss, a low MCV (iron deficiency) anemia, and a positive fecal occult blood test, the diagnosis is cancer until proven otherwise. Gastric cancer is uncommon in the United States

but is one of the most common cancers worldwide, particularly in Asia and Latin America. In the United States, colon cancer is much more prevalent. However, due to the location of the pain (epigastric), the weight loss, and the patient's Japanese origin, gastric cancer is most likely.

Watch Out

It is important to consider gastric cancer as part of the differential in any patient that presents with upper abdominal pain and weight loss. In the United States, approximately 50% of gastric cancers have already spread past the confines of surgical resectability at the time of diagnosis, resulting in a high mortality rate.

History and Physical**What Is the Prevalence of Gastric Cancer and What Causes It?**

Gastric cancer is common in Asia, particularly Japan, Korea, and China where it is the leading cause of cancer-related death. Gastric adenocarcinoma accounts for approximately 90% of all gastric cancers and is uncommon in the United States. This is predominately due to the identification and eradication of endemic *Helicobacter pylori*, with triple therapy (amoxicillin, clarithromycin, and omeprazole) as well as the introduction of refrigeration which led to improvement in food storage and a decrease in salt preservation, pickling, or smoking of meat. Due to the low prevalence in the United States, the data does not support screening due to limited cost-effectiveness.

- **Risk Factors for the Development of Gastric Cancer**

- Positive family history
- Smoked meats, pickled foods, high nitrates/salts
- Familial polyposis
- Gastric adenomas
- Hereditary nonpolyposis colorectal cancer
- *Helicobacter pylori* infection, causing:
 - Atrophic gastritis, intestinal metaplasia, and dysplasia
- Previous gastrectomy or gastrojejunostomy (>10 years)
- Tobacco use
- Ménétrier's disease
- Type A blood
- BRCA-1 and BRCA-2
- HER-2 gene overexpression
- Peutz-Jeghers syndrome

Watch Out

Peutz-Jeghers syndrome is characterized by hamartomatous (benign) polyps throughout the GI tract and risk of multiple cancers. Children develop small dark-colored spots on the lips and mouth and small bowel obstruction from polyp intussusception.

Watch Out

Risk factors for the development of gastric cancer are multifactorial. There is a synergism between *H. pylori* infections and other risk factors leading to a higher rate of gastric dysplasia and metaplasia.

Why Is the Mortality Rate so High for Gastric Cancer?

Patients present in a delayed fashion due to a combination of vague and nonspecific symptoms. The large size of the stomach lumen permits tumors to grow large before causing symptoms, and early diagnosis is difficult due to the absence of efficacious screening in the United States. Typically, patients are diagnosed at a late stage when the tumor extends beyond locoregional confines. These findings exemplify the importance of diagnostic esophagogastroduodenoscopy (EGD) in patients that are high risk.

What Are the Most Common Symptoms/Signs for a Patient with Gastric Cancer? What Are “ALARM” Symptoms/Signs?

The challenge of diagnosing gastric cancer is that the early symptoms are the same as those seen in benign diseases such as gastritis, peptic ulcer disease, or simply indigestion. These symptoms, termed dyspepsia (indigestion), include upper abdominal fullness, heartburn, nausea, belching, or upper abdominal pain. A key to the diagnosis of cancer is that these “benign” symptoms fail to resolve after 6 weeks of antacid therapy or the presence of dyspepsia *in combination* with so-called “ALARM” symptoms/signs:

- **ALARM Symptoms**

- Anemia (iron deficiency)
- Loss of weight
- Anorexia
- Recent onset of progressive symptoms
- Melena/hematemesis
- Dysphagia
- Dyspepsia and Age >55 years

Watch Out

Patients with “ALARM” symptoms are more likely to have gastric cancer, more likely to have advanced cancer at diagnosis, and more likely to have shorter survival. The presence of “ALARM” symptoms mandates upper GI endoscopy.

Are There Specific Findings on Physical Exam for Gastric Cancer?

Physical exam findings are usually nonspecific and often absent. If the patient does have physical findings, it is likely they also have advanced, incurable disease. These include a palpable epigastric mass, palpable left (not right) supraclavicular adenopathy (Virchow's node), periumbilical lymphadenopathy (Sister Mary Joseph node), and left axillary adenopathy (Irish's node).

Pathophysiology

What Is the Vascular Supply to the Stomach?

It is important to understand the blood supply to the stomach as this is how gastric cancer spreads. There are four major arteries: the left and right gastric arteries on the lesser curve and the left and right gastroepiploic arteries along the greater curve, all of which are derived from the celiac artery. The left gastric is a direct vessel off the celiac artery. The right gastric most commonly is a branch of the common hepatic artery. The left and right gastric arteries communicate on the lesser curvature of the stomach. The right gastroepiploic artery is a branch from the gastroduodenal artery which originates from the common hepatic artery, and the left gastroepiploic artery is a branch of the splenic artery. These two communicate and supply blood to the greater curvature of the stomach. Additionally, the short gastric arteries come off the splenic artery and supply the greater curvature.

Why Do Patients with Gastric Cancer Get Iron Deficiency Anemia?

Anemia is due to slow intermittent bleeding of the tumor (which often begins as an ulcer). As the patient loses blood through the GI tract in the form of melena, there is also iron and heme loss along with red blood cells.

What Is an Intestinal-Type Gastric Adenocarcinoma?

This well-differentiated cell type arises from the gastric mucosa and is usually located in the distal stomach. It is more commonly seen in the sporadic patient that has exposure to environmental factors such as poor diet, smoking, and alcohol. This type has decreased with the eradication of *H. pylori* and other detrimental risk factors. Intestinal type accounts for 50% of all gastric adenocarcinomas and has a stepwise histologic pattern of progression starting from an *H. pylori*-induced inflammatory reaction (acute gastritis) and ultimately leading to gastric carcinoma in 10–20 years.

■ Table 51.2 Types of gastric adenocarcinoma

Intestinal	Diffuse
Well differentiated	Poorly or undifferentiated
Distal stomach	Anywhere, but most often proximal stomach
Secondary to environmental factors	Secondary to congenital disorders such as hereditary diffuse gastric cancer (HDGC)
Decreasing in incidence	No change in incidence
Discrete mass	Generalized gastric hypertrophy
Progressive evolution to cancer over years	Aggressive and rapid progression

What Is a Diffuse-Type Gastric Adenocarcinoma?

This is a poorly differentiated tumor, believed to originate from the lamina propria of the stomach and grows in an infiltrative, submucosal pattern. Contrary to the intestinal type, the unorganized growth pattern does not lead to a discrete mass but rather to gastric thickening. Diffuse-type gastric adenocarcinomas are most often found in the proximal stomach near the cardia. These patients do not follow the typical histologic progression of atypia, instead jumping directly from chronic atrophic gastritis to adenocarcinoma and can do so relatively rapidly as compared to the intestinal type. As such, it is seen in younger patients as compared to the intestinal type.

What Is Linitis Plastica?

Diffuse-type gastric cancer (■ Table 51.2) is highly metastatic and aggressive, leading to its rapid progression. It can infiltrate the entire gastric wall, known as “linitis plastica” (plastic lining) named after the stiff, non-distensible gastric wall that develops after it is infiltrated with tumor. This pattern of diffuse submucosal spread lowers the accuracy of endoscopy biopsies and thus presents a diagnostic challenge.

What Is a Gastrointestinal Stromal Tumor (GIST)?

GISTs are mesenchymal tumors of variable malignant potential that originate from the interstitial cells of Cajal (gastrointestinal pacemaker cells) within the GI tract. They are smooth submucosal masses with regular borders. There is near-universal expression of c-KIT and CD-117 by GISTs. Biopsy is not necessary or recommended if there is a high

endoscopic or radiographic suspicion for this tumor. Unlike adenocarcinomas, GISTs rarely spread through lymphatics, making a major gastrectomy frequently unnecessary and routine lymph node dissection is *not* required.

Does Lymphoma Occur in the Stomach?

The stomach is the *most common site* for a gastrointestinal lymphoma. The two most common types are lymphoma of the mucosa-associated lymphoid tissue (MALT) and diffuse large B-cell lymphoma. They account for nearly 90% of all gastric lymphomas. MALT is most commonly associated with an *H. pylori* infection and can be completely treated with triple therapy against *H. pylori*. CHOP chemotherapy (cyclophosphamide, doxorubicin, vincristine, and prednisone) followed by radiation is the therapy of choice for high-grade lymphoma or that which does not respond to *H. pylori* therapy alone.

Workup

What Is the Best Way to Work Up a Patient with Suspected Gastric Cancer?

Upper endoscopy is the diagnostic procedure of choice. It allows for direct visualization of the gastric mucosa, localization of the tumor for operative planning, and the ability to biopsy suspicious lesions.

Once the Diagnosis of Gastric Cancer Is Established, What Further Staging Is Recommended?

Endoscopic ultrasound (EUS) is performed as it assists with determining if the tumor is locally invasive. EUS provides a more accurate assessment of tumor size, depth, and locoregional lymph node involvement as compared to radiographic imaging. In addition, a chest x-ray is performed for lung metastasis, as well as a CT scan of the chest/abdomen/pelvis to rule out other metastasis (liver, distant suspicious lymph nodes) which may have been missed on EUS, either of which would preclude a curative resection (■ Fig. 51.1). Recently, positron emission tomography scan (PET scan) has been proven to highly accurate in detecting small metastases and lymph node involvement and is rapidly becoming standard of care for staging.

Watch Out

In patients with locally advanced gastric cancer, chemotherapy is effective when used prior to surgery. However, surgery is still considered first-line therapy when curative resection can be achieved and not otherwise precluded.



■ Fig. 51.1 Axial CT of gastric adenocarcinoma showing a thickened stomach wall and a metastatic gastrosplenic mass. Black arrows: thickened stomach. White arrows: gastrosplenic mass

Management

How Is Gastric Cancer Treated?

The management of gastric adenocarcinoma is dependent on how advanced the tumor is. Surgical resection (gastrectomy) is the only curative therapy. However, a multi-therapeutic approach is becoming increasingly recommended for locally advanced tumors. This includes neoadjuvant (preoperative) chemotherapy, then surgical resection, followed by adjuvant (postoperative) chemotherapy, or chemoradiation. Chemotherapy has been proven to be effective both the pre- and post-operatively. The MAGIC trial was the first study to show the effectiveness of perioperative chemotherapy prior to surgical resection, with improved outcomes and survival (■ Fig. 51.2).

Watch Out

At least 16 lymph nodes are necessary for adequate staging of gastric adenocarcinoma.

What Is the Role of HER-2 Gene Amplification and Chemotherapy?

HER-2 overexpression has been recognized as a molecular abnormality that increases the aggressive nature of breast cancer. More recently, evidence reveals the role of HER-2 overexpression in gastric cancer patients leading to poorer outcomes and more aggressive disease. Similar to breast cancer, the HER-2 gene has been recognized to respond to certain chemotherapy agents, such as trastuzumab, and therefore, patients with gastric cancer should have genetic testing for the HER-2 gene prior to the induction chemotherapy.

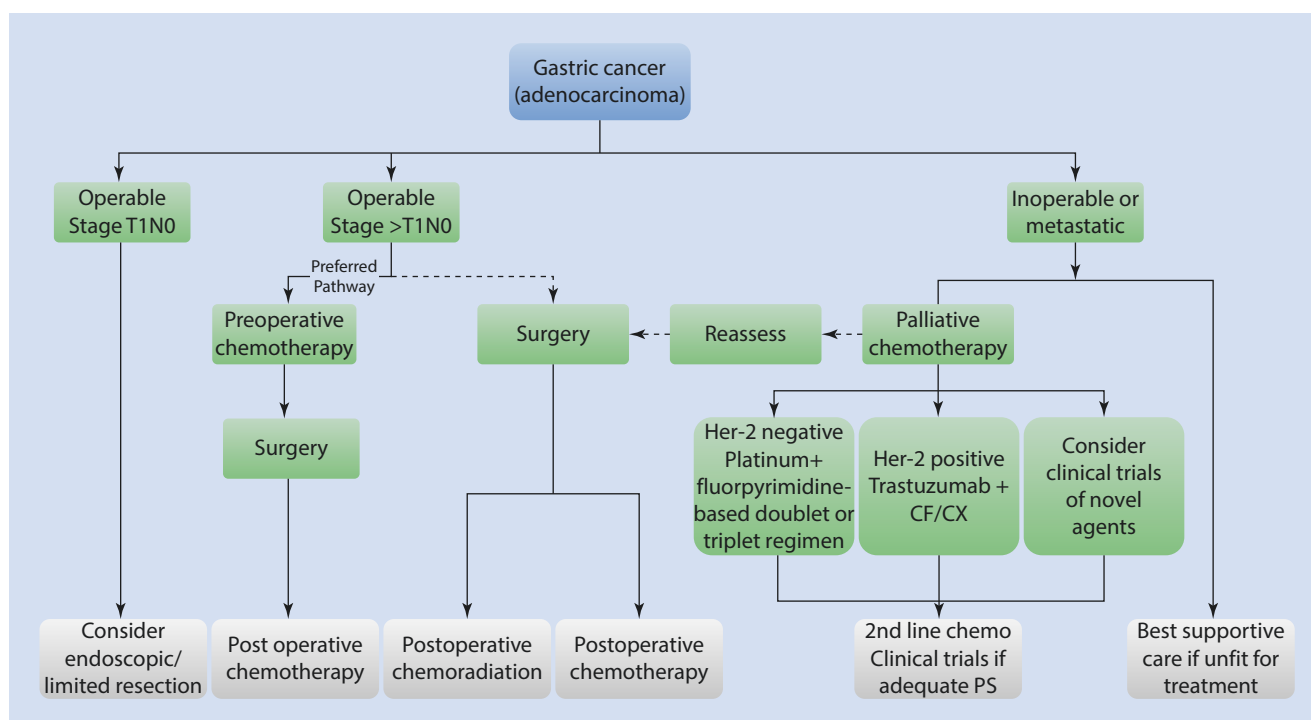


Fig. 51.2 Algorithm for gastric cancer

Complications

What Are the Common Complications that Can Occur After a Gastric Resection?

- Diarrhea
- Early satiety
- Dumping syndrome
- Anastomotic leak
- Afferent limb syndrome
- Internal hernia
- Small bowel obstruction
- Marginal ulceration

How Are Anastomotic Leaks Identified and Treated?

Patients with anastomotic leaks in the gastrointestinal tract will present with abdominal pain and varying degrees of peritonitis, fever, tachycardia, leukocytosis, and sepsis if not treated rapidly. If the patient is stable with no signs of peritonitis and there is concern for a gastric leak, an upper GI study with gastrografin can confirm the diagnosis. The primary treatment in any patient that has an anastomotic leak is source control. This involves either CT-guided drainage or reoperation. If the leak is small, repair of the suture line and an abdominal washout and drainage are often all that is needed.

Watch Out

The initial management of a gastrointestinal anastomotic leak is source control with CT-guided drainage and NPO (not resection and/or diversion).

Summary of Essentials

History and Physical

- Gastric cancer is more common in men than women.
- ALARM symptoms: anemia, loss of weight, anorexia, recent onset of progressive symptoms, melena/hematemesis or mass, swallowing difficulty, dyspepsia with age >55 yrs.
- Often diagnosed late.
- Once symptoms are present, cancer is already advanced.

Pathophysiology

- The most common type: adenocarcinoma.
- Two types of gastric adenocarcinoma: intestinal and diffuse.
- More common in Asian countries.
- The most common cause: *H. pylori* infection.

- Intestinal-type gastric cancer occurs in the distal stomach and is usually associated with environmental factors.
- Diffuse type is poorly differentiated, occurs most often in the proximal stomach, and is often related to congenital disorders (HDGC).
- Linitis plastica is the infiltration of the entire gastric wall with cancer in the submucosal plane (high mortality rate).
- GIST tumors are smooth, submucosal tumors that express c-KIT and CD-117.

Workup

- Endoscopy is the study of choice for diagnosis.
- Further staging with chest x-ray, CT of the chest, abdomen, and pelvis, EUS, and/or PET scan.

Management

- Preoperative chemotherapy, then surgical resection, followed by postoperative chemotherapy, or chemoradiation.

- An alternative to pre and post operative chemotherapy is to only administer chemotherapy (or chemoradiation) postoperatively.
- Low-grade MALT lymphoma is treated with *H. pylori* eradication; high-grade lymphoma requires chemotherapy.

Prognosis

- Five-year mortality remains high as most patients present with advanced disease at diagnosis.

Suggested Reading

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Chest Pain After Vomiting

Tiffany T. Pham and Brian R. Smith

Case Study

A 55-year-old alcoholic male presents to the emergency department after experiencing severe chest pain. He is an obese male with a significant medical history that includes coronary artery disease, sleep apnea, hypercholesterolemia, as well as early liver cirrhosis secondary to alcohol abuse. The patient states the chest pain started about 18 hours ago, after consuming far too much food at a

buffet and binge drinking leading to him feeling ill and forcefully vomiting. There was no blood in the vomitus. He states the pain is in his lower chest and radiates to the left side, back, and upper abdomen. The pain is aggravated by swallowing. At initial exam, his blood pressure is 105/90 mmHg, heart rate is 120/min, respiratory rate is 26/min, and temperature is 38.6 °C. He has crepitus

with palpation around the sternum. His abdomen is soft and non-tender. A chest x-ray shows a left-sided pleural effusion. Laboratory examination is significant for a white blood count of $17 \times 10^3/\mu\text{L}$ (normal $4.1\text{--}10.9 \times 10^3/\mu\text{L}$) with 15% bands (normal <5% bands). Serum troponin-I is 0.1 ng/mL (normal <0.4 ng/mL).

52

Diagnosis

What Is the Most Likely Diagnosis?

Table 52.1

Diagnosis	Comments
<i>Myocardial infarction</i>	Chest pain, more on the left side, left arm and jaw pain, diaphoresis, ST-segment elevation, and elevated troponins
<i>Pericarditis</i>	Substernal, pleuritic chest pain, worse supine, better leaning forward, fever, tachycardia, friction rub, pulsus paradoxus
<i>Pneumothorax</i>	Chest pain, shortness of breath, tachycardia, decreased/absent breath sounds on the affected side
<i>Pneumonia</i>	Shortness of breath, fever, fatigue, productive cough, and decreased breath sounds on the affected side
<i>Aortic dissection</i>	Shearing or tearing chest pain radiating to upper back, shortness of breath, differences in blood pressure in arms, impending doom, severe hypertension, history of Marfan syndrome
<i>Peptic ulcer disease</i>	Postprandial epigastric abdominal pain, nausea, vomiting, bloating
<i>Acute pancreatitis</i>	Epigastric pain radiating to the back, nausea, vomiting, anorexia, cholelithiasis, alcohol abuse, elevation of amylase/lipase
<i>Mallory-Weiss tear</i>	Forceful vomiting and retching, followed by upper GI bleed, typically in alcoholic or bulimic patients, often resolves spontaneously
<i>Boerhaave's syndrome</i>	Forceful vomiting and retching, followed by chest pain and sepsis typically in alcoholic or bulimic patients, crepitus with palpation around the sternum, left-sided pleural effusion

Watch Out

Boerhaave's syndrome has high mortality if not recognized and treated in a timely fashion. The mortality rate is significantly greater in those that have a delay in diagnosis beyond 24 hours.

What Is the Most Likely Diagnosis?

In a patient presenting with chest pain after forceful vomiting (retching), accompanied by crepitus with palpation around the sternum, a left-sided pleural effusion, and evidence of a systemic inflammatory response (fever, tachycardia, leukocytosis with a left shift), the most likely diagnosis is Boerhaave's syndrome, a type of spontaneous esophageal rupture.

History and Physical

What Are the Risk Factors for Boerhaave's Syndrome?

Alcoholic patients have the greatest risk. Binge drinking places patients at risk of forceful vomiting/retching. It can also occur in patients who overeat, which results in aggressive vomiting, and in those with a hiatal hernia. It most commonly occurs in males 50–70 years old.

Why Is Boerhaave's Syndrome so Often Unrecognized?

There is a robust differential for a patient who presents with chest pain. Since its manifestations mimic so many other diseases, esophageal perforation often goes unsuspected or misdiagnosed.

What Is Mackler's Triad?

The principal symptoms include sudden lower thoracic pain, sometimes radiating to the back and aggravated by swallowing. *Mackler's triad* (vomiting, thoracic pain, and subcutaneous emphysema) is highly suggestive of the diagnosis of Boerhaave's syndrome. All three parts of the triad are found in less than 1/3 of cases, which often leads to a delay in diagnosis. The clinical signs most often observed, in decreasing order of frequency, are vomiting (84%), thoracic pain (79%), dyspnea (53%), epigastric pain (47%), and dysphagia (21%).

What Is the Most Specific Sign of an Esophageal Rupture?

Subcutaneous emphysema after forceful retching is pathognomonic for esophageal rupture. This is identified on physical exam by crepitus with palpation around the sternum. Unfortunately, this finding is not very sensitive, as it is seen in only 27% of patients. Due to the heart beating against air-filled tissues, *Hamman’s sign* can be heard over the precordium in mediastinal emphysema. Hamman’s sign is a crunching, rasping sound, synchronous with the heartbeat.

How Does Boerhaave’s Syndrome Differ from Mallory-Weiss?

Table 52.2		
	Boerhaave’s syndrome	Mallory-Weiss
Population	Alcoholics/bulimics after forceful vomiting	Alcoholic/bulimics after forceful vomiting
Pathophysiology	Full-thickness rupture of the esophagus secondary to increased intragastric pressure	Partial tear of mucosa/submucosa in stomach cardia at gastroesophageal junction, secondary to increased intragastric pressure
Presentation	Thoracic pain radiating to back, left-sided pleural effusion, shortness of breath	Hematemesis
Natural course	Can progress to sepsis and death; most often will require immediate surgical repair and drainage	Most resolve spontaneously; surgery rarely indicated

Pathophysiology

What Are the Most Common Causes of Esophageal Perforation?

An esophageal perforation is a rare incident that often constitutes a surgical emergency. Despite improvements in detection and management, esophageal perforation remains a highly fatal disease with mortality rates reported as high as 40%. The majority of perforations (approximately 60%) are the result of an iatrogenic injury with *upper endoscopy perforation* being the most common cause. Other causes may include blunt or penetrating trauma, foreign body ingestion,

or a perforating malignancy. The final 10–20% of perforations account for “spontaneous” ruptures, also known as Boerhaave’s syndrome. Forceful vomiting causes a dramatic rise in intragastric pressure which is transmitted to the esophagus in the presence of a relaxed lower esophageal sphincter. If such a rise in pressure within the esophagus occurs in conjunction with a failure of relaxation of the cricopharyngeus muscle, then tremendous pressures are transmitted to the esophageal wall, leading to perforation.

Why Do Patients with Boerhaave’s Syndrome Become So Septic?

The esophageal perforation leads to gross contamination of the mediastinum, predominately with saliva—one of the dirtiest fluids in the body—but also with gastric and refluxed biliary contents. The perforation often leads to rupture of the pleura as well, which is likely secondary to the gastric and biliary contents eroding through the lining. Once the pleura has been disrupted, gross contamination of the pleural cavity also occurs. It is the mediastinitis and pleuritis that eventually lead to sepsis and multiorgan failure and, if left untreated, will ultimately result in death.

Watch Out

The esophageal tear in Boerhaave’s syndrome typically occurs 3–5 cm above the gastroesophageal junction on the *left* side.

Workup

What Is the First Step in Workup for a Patient Suspected of Having Boerhaave’s Syndrome?

When a patient presents with chest pain and sepsis, esophageal perforation should be suspected. The initial study should be a chest radiograph. The most common findings are a left-sided pleural effusion and atelectasis. A left-sided pneumothorax may also be present. The x-ray findings are usually left sided. It should be noted, however, that a normal chest x-ray will be seen in 12–33% of patients. Normal radiograph findings may be due to a multitude of factors, the most common being the time interval between the perforation and the study. It is believed to take at least 1 hour post-perforation for pneumomediastinum to present on imaging.

What Is the Role of Oral Contrast Studies in Diagnosing Boerhaave’s Syndrome? How About CT?

Oral contrast studies have a higher sensitivity for diagnosing esophageal perforations and therefore should be performed following a questionable chest x-ray to confirm the diagnosis.

Originally it was thought that an esophagogram with gastrografen should be performed as it was recognized to have a sensitivity of 90%. However, current recommendations are to perform a CT with oral contrast because the sensitivity is even higher than that of an esophagogram. Additionally, it allows one to identify the extent of perforation into surrounding structures, while assisting with the decision on a surgical approach. Finally, if the patient is found not to have Boerhaave's syndrome, a CT scan may enable the clinician to make the appropriate differential diagnosis more rapidly (i.e., aortic dissection, pericarditis, pneumonia).

What Type of Contrast Should Be Used?

The ideal contrast for suspected esophageal perforation is controversial. Barium is highly toxic to the peritoneum, so it is contraindicated when bowel perforation is suspected. Barium does not appear to be as harmful to the mediastinum. Gastrografen, if aspirated, can cause severe pneumonitis. For suspected esophageal perforation, CT is the initial procedure of choice with gastrografen as the oral contrast agent. Following esophageal surgery, a gastrografen swallow is often performed to rule out an anastomotic leak, and if negative, it is followed by barium as it is better at detecting small leaks.

Is There a Role for Endoscopy During Diagnosis?

There is generally no role for endoscopy when perforation is suspected. The concern is that insufflation of air may re-open a sealed perforation or enlarge the perforation.

Management

What Are the Initial Steps in the Management of a Patient with Boerhaave's Syndrome?

As soon as the diagnosis of Boerhaave's syndrome is made, medical management should be initiated in an attempt to treat sepsis and/or septic shock. This includes initiating the sepsis bundle. The patient should be given aggressive intravenous fluid resuscitation, placed NPO, and immediately started on broad-spectrum antibiotics that cover oral bacteria, *as well as an antifungal*. An H_2 blocker or proton pump inhibitor should also be initiated to reduce gastric acid secretions. If the patient presents with evidence of severe sepsis, fluid resuscitation should be targeted (mean arterial pressure, urine output, blood pressure, heart rate, lactate). In a septic patient with hemodynamic instability, an arterial line should also be placed, especially if vasopressors are initiated, as it will allow better monitoring of blood pressure.

Watch Out

Remember to start antifungals, in addition to antibiotics in patients with esophageal or gastric perforations.

What Is the Sepsis Bundle?

First published in 2004, and recently updated in 2018, the Surviving Sepsis Campaign has published a set of guidelines known as the Surviving Sepsis Bundle which serves as the cornerstone in the management of patients presenting in septic shock. This has been demonstrated to improve survival. The most important change in 2018 was that the 3- and 6-hour bundles were combined to a single "hour-1-bundle" to emphasize the importance of starting all elements of the bundle within 1 hour of presentation.

Surviving Sepsis Bundle

- Measure serum lactate and remeasure if >2 mmol/L.
- Administer broad-spectrum antibiotics.
- Obtain blood cultures prior to administration of antibiotics (if it does not delay initiating antibiotics).
- Rapid administration of 30 mL/kg crystalloid for hypotension or lactate >4 mmol/L.
- Initiate vasopressors if patient is hypotensive during or after fluid resuscitation to maintain mean arterial pressure >65 mmHg.

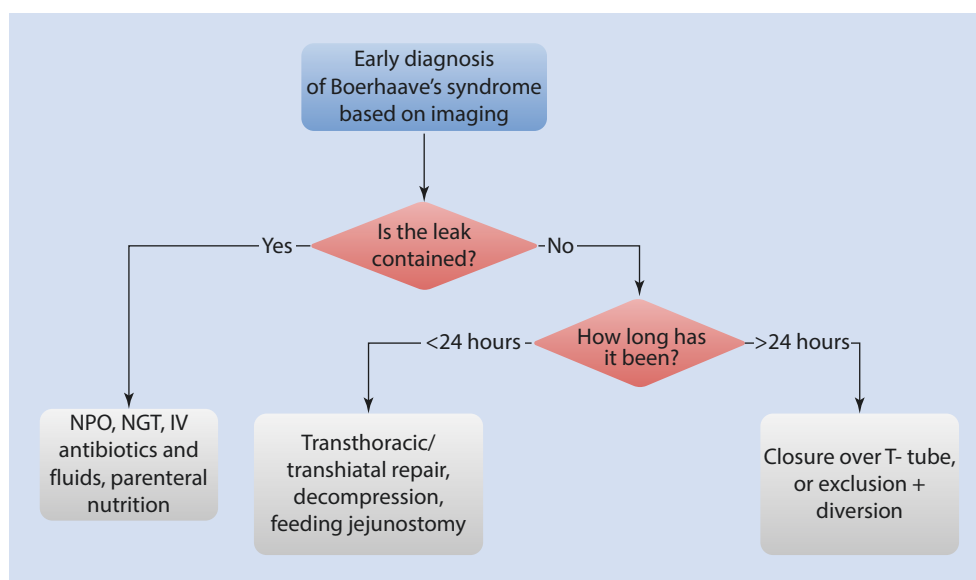
Does the Time Interval Between Perforation and Intervention Matter?

Yes, time is of the essence. The key to optimum management is the early detection and treatment, ideally within 24 hours. A systematic review of over 700 patients showed that treatment delays greater than 24 hours doubled the mortality rate. Once the diagnosis is made, a variety of treatment options are available, ranging from conservative management to options as aggressive as an esophagectomy (■ Fig. 52.1). Endoscopic interventions (e.g. stent placement) are now becoming more widely available and may be a new option for physicians to consider in select patients (but again endoscopy should not be part of the initial diagnosis).

What Constitutes Conservative Management, and Which Patients Are Candidates for It?

Historically, all patients with a spontaneous perforation received surgical management. However, nonoperative (conservative) management is now considered in a select group of patients and includes continuous nasogastric suction (with careful insertion), intravenous broad-spectrum antibiotics/antifungals, and parenteral nutrition. Conservative manage-

Fig. 52.1 Algorithm for the treatment of a patient with Boerhaave's syndrome



ment is an accepted treatment in patients with minimal comorbidities, no signs of sepsis or septic shock, a perforation that has been present for less than 24 hours, and a leak that is small and contained or has sealed itself—which happens often. Repeat imaging may occur at hospital day 4 or 5 to evaluate for spontaneous closure of the perforation. If there are no signs of extravasation, oral liquid intake may be resumed. Oral antibiotics should be continued for 1–2 weeks, depending on the clinical picture. Currently, there is an approximate 10% failure rate using medical management.

What Are the Surgical Options for a Patient with Boerhaave's Syndrome?

If the esophageal perforation has not spontaneously sealed (free leakage into mediastinum or chest), surgery is recommended via a thoracotomy. The approach to surgical management is dependent on the time interval from perforation to diagnosis (greater or less than 24 hours), the location and size of the perforation, the degree of devitalized tissue, and the status of the patient (hemodynamically stable or unstable, medical comorbidities). The two main options are primary closure of the perforation and esophageal resection. Primary closure is preferred especially if the perforation is small and recent. All devitalized tissue surrounding the perforation must be debrided in order for surgical treatment to be successful. This includes debridement of the mediastinum as well as the pleura. Following suture closure of the perforation, a reinforcement flap (consisting of a strip of pleura and/or intercostal muscle) should be placed over the suture line to support the closure as well as decrease the chance of a leak, followed by copious irrigation and drainage. With a large hole, or with a prolonged delay, successful primary closure is unlikely, and esophagectomy will be needed. The esophagus is later recon-

structed with interposed colon or jejunum. The most favorable outcome appears to be obtained in patients that are treated within 24 hours of injury and receive a primary closure of the perforation.

What Is the Prognosis of a Patient with Boerhaave's Syndrome?

The mortality rates of Boerhaave's syndrome exceed 90% if left untreated and up to 40% after surgical intervention. Death occurs secondary to contamination of the mediastinum and pleura, which eventually leads to sepsis, septic shock, and multiorgan failure. However, surgical repair within 24 hours carries a 75% survival rate. Delayed time to the operating room is associated with increased mortality. Patients with small, contained leaks without signs of sepsis can be managed nonoperatively with good outcomes.

Area of Controversy

What Are the Endoscopic Options for a Patient with Boerhaave's Syndrome?

Endoscopic-covered stent placement for Boerhaave's syndrome can be considered in patients with extensive underlying comorbidities who are unlikely to tolerate surgery. Endoscopic therapy should be performed by a skilled endoscopist who is experienced in esophageal stent placement and after discussion with a thoracic surgeon. Observational studies have suggested a higher reintervention rate with stents when compared with surgery. Although stents are being used more often, they are not yet considered the standard of care but likely soon will be. Further clinical trials need to be carried out to evaluate its use.

Summary of Essentials

History and Physical

- Alcoholic and bulimic patients after forceful emesis at risk for Boerhaave's syndrome.
- Most commonly occurs in males 50–70 years with an alcohol or overeating history.
- Iatrogenic injury by upper endoscopy is the most common cause of esophageal perforation.
- Boerhaave's syndrome most commonly presents with thoracic pain radiating to lower back and aggravated by swallowing.
- Mackler's triad (chest pain, vomiting, and subcutaneous emphysema) is suggestive of Boerhaave's syndrome but is found in less than 1/3 of cases.

Pathophysiology

- Boerhaave's syndrome is a transmural esophageal perforation secondary to increased intragastric pressure induced by vomiting; Mallory-Weiss is from a partial-thickness tear.

Workup

- Chest x-ray should be the initial study; look for left-sided pleural effusion, atelectasis, pneumothorax; can be normal in early disease.
- Pneumomediastinum after vomiting is pathognomonic.
- Gastrografin esophagogram or CT scan of the chest with water-soluble oral contrast should be performed to confirm the diagnosis.
- Serum lactate, blood cultures.

Management

- Initiate sepsis bundle.
- The time interval between perforation and intervention is critical to the outcome (within 24 hrs).
- Conservative management with continuous nasogastric suction, intravenous broad-spectrum antibiotics/antifungals, IV fluids, and parenteral nutrition may be considered in healthy patients who have mild sepsis and a sealed perforation or small perforation contained within the mediastinum.
- Gold standard (and with free perforation into chest) is left thoracotomy, with debridement of the necrotic tissue surrounding the perforation, primary suture closure, and coverage with a pedicle flap (pleura, fundoplication, omentum), and wide drainage.
- Endoscopic stents are being used more often, but this is not yet considered the standard of care.

Suggested Reading

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- Horwitz B, Krevshy B, Buckman RF Jr, Fisher RS, Dabezies MA. Endoscopic evaluation of penetrating esophageal injuries. *Am J Gastroenterol*. 1993;88(8):1249–53.
- Levy MM, Evans LE, Rhodes A. The surviving sepsis campaign bundle: 2018 update. *Intensive Care Med*. 2018;44:925–8.
- Scheigert M, Beattie R, Solymosi N, Booth K, Dubecz A, Muir A, Moskorz K, Stadhuber RJ, Ofner D, McGuigan J, Stein HJ. Endoscopic stent insertion versus primary operative management for spontaneous rupture of the esophagus (Boerhaave syndrome): an international study comparing the outcome. *Am Surg*. 2013;79:643.

Question Set: Upper Gastrointestinal

Questions

1. A 65-year-old male presents with melena. He reports no abdominal pain and no vomiting. He denies a prior similar history. In the emergency department, he is tachycardic to 120/min with a blood pressure of 112/80 mmHg. Hemoglobin and hematocrit are 9.2 g/dL (normal 13–16 g/dL) and 28% (40–52%), respectively. Past history is significant for an aortobifemoral bypass 5 years earlier for severe claudication. Nasogastric (NG) tube aspiration returns clear fluid. The patient is admitted to the ICU for resuscitation, the melena ceases, and the hematocrit stabilizes. Upper endoscopy is negative, with no stigmata of bleeding. Following a bowel prep, colonoscopy is also negative. CT scan of the abdomen reveals gas around the proximal aortic graft. Which of the following is true about this condition?
- (A) Formal angiography is likely to demonstrate the source of bleeding.
 - (B) Gas around the aortic graft is not considered pathologic.
 - (C) The aortic graft will likely need to be removed.
 - (D) Rebleeding is rare.
 - (E) This represents an occult bleed.
2. What is the most common cause of an esophageal perforation?
- (A) Boerhaave's syndrome (spontaneous perforation)
 - (B) Iatrogenic
 - (C) Foreign body
 - (D) Esophageal cancer
 - (E) Trauma
3. Which of the following is true of Boerhaave's syndrome?
- (A) It most often presents with upper GI bleeding.
 - (B) It is most often caused by an iatrogenic injury.
 - (C) It is a partial-thickness tear of the esophagus.
 - (D) It is the most lethal GI perforation.
 - (E) Treatment consists of bowel rest and intravenous antibiotics.
4. A 50-year-old Asian female complains of abdominal discomfort and weight loss. She has an esophagogastroduodenoscopy (EGD) performed, and biopsy of a stomach lesion returns as mucosa-associated lymphoid tissue (MALT) lymphoma. Which of the following is the best treatment plan for this patient?
- (A) Chemotherapy
 - (B) Radiation therapy
 - (C) Combined chemotherapy and radiation
 - (D) Clarithromycin, amoxicillin, and a proton pump inhibitor
 - (E) Gastric resection
5. Which of the following is the first step in the treatment of a patient with Boerhaave's syndrome?
- (A) Esophagectomy
 - (B) Gastric decompression
 - (C) Drainage of the mediastinum and pleura
 - (D) Primary repair of the perforation with advancement flap coverage
 - (E) Fluid resuscitation and IV antibiotics

6. A 65-year-old male presents with iron deficiency anemia. Fecal occult blood testing is positive. Upper endoscopy demonstrates an irregular ulcer in the body of the stomach. Biopsy confirms adenocarcinoma. Endoscopic ultrasound (EUS) demonstrates that the mass has invaded into the submucosa. No enlarged nodes are seen around the lesion. Which of the following would be the next best step in the management?
- (A) Proceed to gastric resection
 - (B) CT scan of the abdomen
 - (C) PET scan
 - (D) Laparoscopy
 - (E) Chemotherapy
7. A 50-year-old female presents with massive upper GI bleeding. In the emergency room, she is actively vomiting large amounts of bright red blood. She appears to be lethargic and pale. Blood pressure is 70/50 mmHg, heart rate is 120/min, and respiratory rate is 22/min. The next step in the management is:
- (A) Emergent upper endoscopy
 - (B) Immediate orotracheal intubation
 - (C) Place bed in reverse Trendelenburg position
 - (D) Give two-liter bolus of normal saline
 - (E) Give two units of O-negative blood
8. A 48-year-old male presents with vomiting of bright red blood. He states that he has had a 1-month history of epigastric pain that is relieved by eating food. He denies weight loss. He does not take any medications or drink alcohol. He is hemodynamically stable in the emergency department. Following resuscitation, the patient undergoes upper endoscopy which reveals a posterior ulcer in the proximal duodenum which is actively bleeding. Despite numerous attempts at cauterization and injection with epinephrine, the gastroenterologist reports that she cannot stop the bleeding and the blood pressure drops to 70/50 mmHg. The next step in the management is:
- (A) Angiographic embolization
 - (B) Transfer to ICU for ongoing transfusion of blood
 - (C) Administer vasopressin
 - (D) Exploratory laparotomy
 - (E) Administer octreotide
9. A 45-year-old male with a history of alcohol abuse presents to the emergency department with an upper GI bleed after a night of binge drinking. The patient reports that he repeatedly dry heaved, after which he began to note bright red blood in the vomitus. He is afebrile with normal vital signs. Upper endoscopy reveals a partial tear in the mucosa and submucosa of the stomach near the gastroesophageal junction. Which of the following is true about this condition?
- (A) It is usually related to portal hypertension.
 - (B) It is often associated with a left pleural effusion.
 - (C) It is associated with *H. pylori* infection.
 - (D) The bleeding is likely arising from the gastroduodenal artery.
 - (E) The bleeding most often stops spontaneously.
10. A 60-year-old male presents with gnawing epigastric pain that has been present for 8 weeks. The pain seems to get worse with eating. He denies nausea, vomiting, or early satiety. He has lost 10 lbs and he attributes this to a poor appetite. He denies black or bloody stools. Physical examination is unremarkable. What is the next study to be ordered?
- (A) Barium swallow
 - (B) CT scan
 - (C) Esophagogastroduodenoscopy (EGD)
 - (D) Six-week trial of proton pump inhibitor
 - (E) Testing for *H. pylori*

11. Which of the following is the strongest risk factor for gastric cancer?
- (A) Type A blood
 - (B) *H. pylori* infection
 - (C) Smoking
 - (D) Familial adenomatous polyposis
 - (E) Family history
12. A 70-year-old male with a history of smoking presents with vague upper abdominal and epigastric pain and coffee ground emesis. On esophagogastroduodenoscopy (EGD), a small ulcer is found in the stomach, with evidence of a large submucosal mass underneath the ulcer. Biopsy of the area is negative. CT scan confirms a 4-cm homogeneous, well-circumscribed, submucosal mass in the greater curvature of the stomach. What does this mass most likely represent?
- (A) Gastrointestinal stromal tumor (GIST)
 - (B) Gastric adenocarcinoma
 - (C) Gastric lipoma
 - (D) Metastatic carcinoma
 - (E) Solitary fibrous tumor
13. A 65-year-old female presents with recurrent coffee ground emesis. She has had vague upper abdominal pain for the past 2 months, relieved by taking antacids. In addition, she reports an involuntary weight loss of 10 lbs. She denies nonsteroidal anti-inflammatory drug (NSAID) or alcohol use. On physical examination, her blood pressure is 110/70 mmHg and pulse is 80/min. Abdominal examination reveals mild epigastric tenderness with no rebound or guarding. Laboratory values are significant for hemoglobin of 8.3 g/dL (normal 12–15 g/dL) and hematocrit of 24% (36–44%) with a mean corpuscular volume (MCV) of 80 fL (80–100 fL), total bilirubin of 3.0 mg/dL (0.1–1.2 mg/dL), alkaline phosphatase of 250 IU/L (33–131 IU/L), GGT of 270 IU/L (6–37 IU/L), ALT of 300 IU/L (<35 IU/L), and AST of 320 IU/L (<35 IU/L). The most likely diagnosis is:
- (A) Duodenal ulcer
 - (B) Gastric ulcer
 - (C) Pancreatic cancer
 - (D) Ampullary cancer
 - (E) Dieulafoy's lesion
14. A young man from Armenia arrives to the emergency department complaining of a progressively bloody cough. He reports night sweats and fevers for the past month. He has been in the United States for 1 week visiting family. As you begin examining him, he coughs up a massive amount (200 ml) of bright red, foamy sputum and has difficulty speaking. Portable chest x-ray shows multifocal patchy and cavitary opacities in the right upper lobe with mediastinal lymphadenopathy. Given his increased risk for asphyxiation, the patient is intubated and placed in a right lateral decubitus position. What is the next best step in management?
- (A) Emergent thoracotomy
 - (B) Bronchoscopy
 - (C) Video-assisted thoracic surgery (VATS)
 - (D) Emergency arteriography
 - (E) INH, rifampin, ethambutol, and pyrazinamide
15. A 50-year-old male presents to the emergency department stating that he passed a large amount of maroon stool earlier in the day. He is currently not passing any stool. He has not vomited. He denies abdominal pain or weight loss. He also has a history of nosebleeds. He takes no medications and does not drink alcohol. Physical examination

is only significant for small red nodules on his lips. Abdominal examination is unremarkable. Upper endoscopy is negative. Which of the following is most likely to localize the site of the GI bleeding?

- (A) Capsule endoscopy
- (B) CT angiogram
- (C) Lower endoscopy
- (D) Formal angiography
- (E) Technetium-labeled red blood cell scan

16. Successful eradication of *H. pylori* is best documented by:

- (A) EGD with biopsy
- (B) Urea breath test
- (C) Blood antibody test
- (D) Stool antigen
- (E) Documentation is unnecessary provided symptoms have resolved

Answers

1. Answer C

GI bleeding, in association with a history of aortobifemoral bypass, is due to an aortoenteric fistula until proven otherwise. Patients typically have a "herald" bleed, followed later by exsanguinating hemorrhage (D). The clear fluid from the NG aspirate helps rule out bleeding from the stomach, but not from the duodenum (would need bilious fluid without blood). Thus, the first diagnostic test of choice is still an upper endoscopy, but in aortoenteric fistulas, it is typically negative as the bleeding results from erosion of the aortic graft into the fourth portion of the duodenum which is usually not well visualized with a standard scope. The negative endoscopy essentially rules out the most common causes of upper GI bleeding which include acute gastritis, as well as gastric and duodenal ulcers. A colonoscopy is generally not useful in the acute bleed setting, as the colon is filled with stool and clot. Thus, bowel prep is necessary. A negative lower endoscopy is less conclusive. Though it rules out colon cancer, other sources of lower GI bleed, such as diverticulosis and arteriovenous malformation, may be hard to see if they are not actively bleeding. Nevertheless, with a negative upper and lower endoscopy, the bleeding is likely coming from the small bowel. This fulfills the definition of an *obscure bleed* (obvious bleeding, as evidenced by the melena, without an obvious source). An *occult* bleed is one that the patient is not aware of (detected only by fecal occult blood testing) (E). The diagnosis of an aortoenteric fistula is notoriously difficult to make. Angiography is poor at showing any abnormalities with an aortoenteric fistula (A). With an aortoenteric fistula, the aortic graft by definition is infected. Air, fluid, or stranding around the graft on CT scan beyond 6 weeks after surgery would be considered pathologic and indicative of a graft infection (B). Treatment is to remove the graft. This can be done either by replacing it with a human cadaver homograft in situ or by performing an axillo-bifemoral bypass followed by removal of the aortic graft and aortic ligation.

2. Answer B

The most common cause of esophageal perforation is iatrogenic injury, usually from esophagogastroduodenoscopy (EGD) but also occasionally from endotracheal intubation or placement of a nasogastric tube. Boerhaave's syndrome, foreign body (especially sharp or corrosive objects), and esophageal cancer may also cause perforation, but they are less common than iatrogenic injury (A, C–D). Trauma, especially of the penetrating variety, may injure the esophagus, but this is less common than iatrogenic injury (E).

- ✓ 3. Answer D
Boerhaave's syndrome is the term used for a perforation of the esophagus that occurs following forceful emesis (iatrogenic perforation is not called Boerhaave's syndrome) (B). The full-thickness tear causes spillage of GI contents into the mediastinum and even the thorax (C). Since GI contents spill into the mediastinum instead of the peritoneum, the patient does not develop peritonitis. Rather, they often present with fever and chest pain. As such, the diagnosis is often delayed until the patient becomes severely septic. Among GI perforations, it has the highest overall mortality. Boerhaave's syndrome most often occurs in males between the ages of 50 and 70, after excessive intake of food and alcohol. Unlike Mallory-Weiss tears, Boerhaave's syndrome does not typically present with upper GI bleeding (A). Treatment is surgical (repair hole in esophagus) (E). Outcomes are dependent on the timeliness of recognition and surgical management.
- ✓ 4. Answer D
MALT lymphoma is strongly associated with *H. pylori* infection and is unique in that it is curable with antibiotics (i.e., triple therapy). In addition to biopsy, testing for *H. pylori* should be performed. After triple therapy, cure should be confirmed. If it is determined that triple therapy has failed, other modalities such as chemotherapy, radiation therapy, a combination of both, and/or surgery are utilized (A–C, E).
- ✓ 5. Answer E
All patients presenting with possible esophageal perforation should receive immediate IV fluids and antibiotics for the treatment of sepsis. Gastric decompression, mediastinal and pleural drainage, and primary repair of the esophagus should occur after initial stabilization, ideally within 24 hours (B–D). Esophagectomy is reserved for extreme cases with large perforation or wherein primary repair will cause stricture (A).
- ✓ 6. Answer B
EUS is performed as it assists with TNM staging. EUS has been proven to provide more accurate assessment of tumor size, depth, and locoregional lymph node involvement compared to radiographic imaging. The next step is to perform a CT scan of the abdomen to look for distant metastasis and confirm that the patient is a surgical candidate. CT scanning will rule out liver metastasis as well as distant suspicious lymph nodes that were missed on EUS, either of which would preclude a curative resection. Though not the standard of care, PET scan is emerging as an accurate modality for detecting small metastases and lymph node involvement (C). The management of gastric adenocarcinoma is dependent on the staging of the tumor. Surgery with gastric resection is the only potentially curative therapy for resectable gastric cancer (A). Laparoscopy is sometimes utilized to look for peritoneal or omental metastasis which would preclude curative gastrectomy (D). Advanced gastric cancer should be considered for a multi-therapeutic approach with chemotherapy (E).
- ✓ 7. Answer B
The patient presented is suffering from a massive, ongoing UGI bleed. Management should always begin with the ABCs. Given the large amount of bleeding, combined with her hemodynamic instability, this patient's airway is at risk. As such, the correct answer is to emergently perform orotracheal intubation. Unlike an elective intubation, it should be performed using a rapid sequence intubation (RSI) technique. Reverse Trendelenburg helps to prevent aspiration, but in the patient presented, it would be potentially dangerous given the marked hypotension (C). Following intubation and confirmation of appropriate placement, 2 liters of normal saline would be administered (D). Given the massive bleeding, blood will also likely need to be administered. However, if the patient responds to the initial fluid bolus, O-blood may not be necessary (E). Following resuscitation, emergent endoscopy to identify and treat the cause of the bleeding should be performed (A). Additionally, a Foley catheter should be placed to monitor urine output as an indication of the patient's volume status.

- ✓ 8. Answer D
The mainstay of therapy for upper GI bleeding is endoscopic intervention. Techniques utilized include injection of epinephrine, sclerosing agents, clips, and cauterization. On rare occasion, if the bleeding cannot be controlled, then urgent surgical intervention is indicated. In the above case, the appropriate intervention is to surgically open the duodenum and oversew the ulcer in four quadrants to assure the artery has been ligated. Continuing blood transfusion alone is not appropriate (B). Although angiographic embolization is occasionally utilized for GI bleeding in poor surgical risk patients, it would not be the first choice in someone who is hemodynamically unstable (A). Vasopressin and octreotide are used in the management of patients suffering from bleeding esophageal varices (C, E).
- ✓ 9. Answer E
The case represents a classic history and endoscopic findings for a Mallory-Weiss tear. The etiology is thought to be a sudden and rapid rise in the transmural pressure gradient at the gastroesophageal (GE) junction, associated with retching. It is most often seen following an alcoholic binge but can also be seen with any forceful vomiting or coughing. It is thought to more likely occur in patients with hiatal hernias. The tear is a longitudinal, partial thickness, in the stomach, near the GE junction. The left gastroduodenal artery is not involved (D). It usually resolves spontaneously. Though it is seen following an alcohol binge, it is not related to portal hypertension, or *H. pylori*, and does not cause a pleural effusion (A–B). Mallory-Weiss is not to be confused with Boerhaave's syndrome, which can also occur after forceful vomiting. In Boerhaave's syndrome, the rapid rise in intrathoracic pressure can cause a *full-thickness perforation* of the esophagus. The esophageal perforation results in esophageal contents spilling into the mediastinum and sometimes into the left chest, resulting in a left pleural effusion, subcutaneous emphysema, severe chest pain, and, if untreated, sepsis and death. Boerhaave's syndrome requires broad-spectrum antibiotics and emergent surgery to seal the esophageal perforation and drain the mediastinal infection.
- ✓ 10. Answer C
Epigastric pain and symptoms of dyspepsia are extremely common. It is reasonable in most young patients to start with a short trial of proton pump inhibitors (D). Alternatively, clinicians can employ the test-and-treat strategy in which they test for *H. pylori* first (E). Testing should only be done if the clinician plans to offer treatment for a positive test. However, in patients >55 years or in those with ALARM Symptoms (*anemia* (iron deficiency), *loss* of weight, *anorexia*, *recent* onset of progressive symptoms, *melen*a/hematemesis, swallowing problems), upper endoscopy is required to rule out gastric cancer. CT scan is usually performed after EGD to evaluate for distant metastasis in patients suspected of having gastric cancer (B). Operative resection should not be undertaken until the diagnosis is confirmed and the tumor is staged. Barium swallow may identify gastric ulcers and infiltrating lesions, but it has a high false-negative rate and does not permit biopsy (A). Barium swallow may also be used to evaluate dyspepsia in younger patients.
- ✓ 11. Answer B
H. pylori is the strongest established risk factor for gastric cancer worldwide. *H. pylori* infections lead to gastritis, and without eradication of the infection, inflammatory changes may eventually lead to dysplasia and metaplasia. All the remaining choices increase one's risk of developing gastric cancer but are not considered to be as strong as *H. pylori* (A, C–E).
- ✓ 12. Answer A
GISTs are mesenchymal tumors that most often occur in the stomach and small intestine. As they grow, they can cause pressure necrosis, leading to erosion of the gastric mucosa and GI bleeding. Since the mass is submucosal, attempts at biopsy at the time of upper endoscopy are often negative and may cause bleeding. CT scan

typically shows a well-circumscribed homogeneous mass. GISTs are caused by a gain of function mutation (tumorigenesis) in the proto-oncogene c-KIT. Treatment is surgical resection, followed by imatinib mesylate, a selective tyrosine kinase inhibitor with action against mutant c-KIT. Gastric adenocarcinoma starts in the mucosa; it would be unlikely to be biopsy negative (B). A lipoma or a solitary fibrous tumor would not likely erode into the mucosa (C, E). Skin cancer can metastasize to the stomach but does not typically present with a well-circumscribed mass (D).

✓ 13. Answer D

The patient is presenting with an unusual combination of an upper GI bleed (coffee ground emesis) and obstructive jaundice (elevated bilirubin and rise in alkaline phosphatase with proportional rise in ALT and AST). Of the five options, ampullary cancer is the one that would most likely present as such. Pancreatic cancer, though it certainly can cause pain, weight loss, as well as obstructive jaundice, is not associated with iron deficiency anemia or upper GI bleed (C). Dieulafoy's lesion typically presents with massive upper GI bleeding, due to an abnormally located superficial arteriole that erodes (E). Diagnosis is difficult as it causes a pinpoint bleed that can only be seen when actively bleeding. Duodenal or gastric ulcers would not cause obstructive jaundice (A–B).

✓ 14. Answer B

Massive hemoptysis with constitutional symptoms as described is likely from tuberculosis (TB). This is further supported by the patient's origin from a TB endemic area (e.g., Armenia, Mexico, Nigeria) and the chest x-ray findings. The most common cause of massive hemoptysis in the world is TB. Immediate intubation is indicated to protect the airway because of the massive amount of foamy sputum preventing him from being able to speak. In addition, any patient with bleeding from a pulmonary source needs to be placed in a dependent position (on the side of the bleeding source) to prevent blood from entering the contralateral lung. This is best done by a right lateral decubitus position in the above patient. The next best step in management involves localizing the source and controlling it with bronchoscopy. Emergent thoracotomy can be considered if initial management options fail to control bleeding (A). VATS offers a minimally invasive surgical technique to treat certain lung and chest wall diseases but is not currently used much in the emergency setting (C). Angiography with embolization is a therapeutic option for massive hemoptysis, particularly if site of bleeding cannot be localized (D). INH, rifampin, ethambutol, and pyrazinamide are used to treat TB but will not address the patient's acute condition (E).

✓ 15. Answer A

Melena can either be from an upper or a lower GI source. The presentation is classic for hereditary hemorrhagic telangiectasia (HHT) (also known as Osler-Weber-Rendu), an autosomal dominant disorder characterized by recurrent epistaxis; telangiectasia/red nodules of the face, lips, and/or GI tract; arteriovenous malformations (AVM); and a family history. GI bleeding most often occurs in the stomach and small bowel. If upper endoscopy is unable to confirm bleeding in the stomach, a capsule endoscopy (gelatin capsule containing a video recorder is swallowed, eventually retrieved in the stool, and permits visualization of the entire bowel) or push enteroscopy is used to assess for small bowel bleeding. Push enteroscopy uses a longer enteroscope or pediatric colonoscope to visualize the proximal jejunum. The subsequent step would be to perform lower endoscopy (after a bowel preparation) (C). However, colonic telangiectasias are very uncommon. Formal angiogram would only be useful if the patient is actively bleeding at a rate of 1 ml/min (the patient is not currently bleeding), is an invasive procedure, and would not permit visualization of the extent of telangiectasias (D). Technetium-labeled red blood cell scan may be useful if the patient is actively bleeding (at a rate of 0.5 ml/min) but is particularly ineffective in localizing the site of bleeding in the small bowel (E). A CT angiogram would not demonstrate telangiectasias of the small bowel (though it would be useful for identifying hepatic AVMs) (B).

✓ 16. Answer B

Eradication may be confirmed by a urea breath test, fecal antigen test, or upper endoscopy performed 4 weeks or more after completion of therapy (D). Typically, non-invasive methods should be performed except in cases when a follow-up endoscopy is indicated (e.g., gastric cancer, preneoplastic lesions, MALT lymphoma) (A). Blood antibody test is unable to confirm eradication as IgG levels will remain elevated after the acute infection is resolved (C). Clinical resolution of symptoms is inappropriate in confirming eradication of *H. pylori*, particularly in the setting of gastric cancer (E).

Urology

Jeremy M. Blumberg

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Scrotal Pain

Areg Grigorian, Fuad F. Elkhoury, and Jeremy M. Blumberg

Case Study

A 14-year-old male presents to the emergency department with nausea, vomiting, and acute onset severe right scrotal pain that started 90 minutes ago while playing soccer. He vomited once soon after pain onset. He denies any trauma. He had a similar past episode 1 year ago that resolved spontaneously 10 minutes after onset. On physical examination, his right testicle is exquisitely tender to palpation, high riding, and fixed in the scrotum. The left testis is normal lying and non-tender with smooth contours. Right cremasteric reflex is absent.

53

Diagnosis

What Is the Differential Diagnosis?

Table 53.1

Diagnosis	Comments
<i>Testicular torsion</i>	Sudden onset, tender and swollen testicle that is displaced superiorly; mass may be felt in spermatic cord, <i>absent cremasteric reflex</i> , nausea, vomiting
<i>Torsion of testicular or epididymal appendage (appendix testis)</i>	Common cause of acute painful hemiscrotum in a child; the epididymal appendage (appendix testis) is located at the head of the epididymis; <i>blue-dot sign</i> is a classic but rare finding; onset of pain is more gradual; <i>cremasteric reflex is maintained</i>
<i>Epididymitis and/or orchitis</i>	Scrotal pain relieved by supporting the scrotum, gradual onset, fever, dysuria, induration; most commonly bacterial etiology; mumps implicated as well; differentiate from other scrotal pathology with scrotal US showing hyperemia of testis/epididymis
<i>Hydrocele</i>	Fluid in the tunica vaginalis, <i>will transilluminate</i> , may increase in size with Valsalva if communicating with peritoneum (usually in children), often spontaneously resolves by 1 year of age; idiopathic etiology in adults; may be reactive to inflammation/orchitis
<i>Varicocele</i>	Tortuous dilation of pampiniform plexus, <i>does not transilluminate</i> ; <i>does</i> increase in size with Valsalva, described as a “bag of worms”; may present as scrotal discomfort; may contribute to male infertility
<i>Appendicitis</i>	Anorexia, vague periumbilical abdominal pain, vomiting, localized right lower quadrant pain (McBurney’s point)

Table 53.1 (Continued)

Diagnosis	Comments
<i>Fournier’s gangrene</i>	Severe necrotizing infection in the perineal and scrotal region occurring most commonly in elderly diabetic patients and immunocompromised
<i>Traumatic testicular rupture</i>	Patients have history of trauma to scrotum, scrotal pain, hematocele and scrotal hematoma; results from a disruption to the connective tissue enveloping the testicle (tunica albuginea)
<i>Testis tumor</i>	Presents as firm, <i>painless</i> testicular mass that does not transilluminate; seminomas (germ cell tumors) are the most common type and are malignant

What Is the Most Likely Diagnosis for this Patient?

A 14-year-old male with acute onset scrotal pain, high riding and tender testicle with horizontal lie, and absent ipsilateral cremasteric reflex has testicular torsion until proven otherwise. Patients may report similar prior episodes.

History and Physical

What Is the Cremasteric Reflex?

The cremasteric reflex is an elevation of the ipsilateral testicle by the cremasteric muscle in response to a stroking motion at the medial aspect of the upper thigh. When the medial thigh is stroked, sensory fibers from the femoral branch of the genitofemoral nerve (L1–L2) are stimulated. The sensory input travels to the spinal cord, where it synapses with the motor nerve from the genital branch of the genitofemoral nerve (L1–L2) to activate the cremasteric muscle and cause ipsilateral elevation of the testis.

What Would Cause an Absent Cremasteric Reflex?

The cremasteric reflex is absent with upper and lower motor neuron disorders, with spinal cord injury at L1–L2 (genitofemoral nerve), when the nerve is accidentally cut during hernia surgery, and usually in patients with testicular torsion. It is important to note that although the reflex is almost always absent in patients with testicular torsion, a present reflex *does not* exclude the possibility of testicular torsion.

What Is Prehn's Sign? Is It Reliable?

Prehn's sign is positive when patients report pain relief with elevation of scrotal contents and negative when this does not relieve any pain. Classically, patients with epididymitis have a positive Prehn's sign, while testicular torsion patients have a negative sign. However, Prehn's sign is not a reliable distinguishing feature between testicular torsion and epididymitis, as a positive sign does not exclude the diagnosis of testicular torsion. Prehn's sign has been shown to be inferior to Doppler ultrasound to rule out testicular torsion.

What Is the Blue-Dot Sign?

This is a pathognomonic sign (■ Fig. 53.1) for torsion of testicular or epididymal appendage (appendix testes). Palpation of the testes reveals a small firm and tender nodule near the head of the epididymis that appears to have a blue discoloration.

What Are the Four Cardinal Symptoms and Signs of Testicular Torsion?

Nausea/vomiting, testicular pain duration of less than 24 hours, a superiorly displaced testicle, and an absent cremasteric reflex.



■ Fig. 53.1 Blue-dot sign. (From Kaplan GW, McAleer IM. Office urology. In: Poppas DP, Retik AB, editors. Pediatric urology. Atlas of clinical urology. London: Current Medicine Group; 2003. Reprinted with permission)

What Are the Important Differences Between Testicular Torsion and Appendix Testes Torsion?

■ Table 53.2

Type	History and physical	Crem-asteric reflex	Management
<i>Testicular torsion</i>	Sudden onset of tender and swollen testicle that is displaced superiorly; mass may be felt in spermatic cord, nausea, vomiting	Absent	Emergent surgery for detorsion, followed by bilateral orchiopexy
<i>Appendix testes torsion</i>	Gradual onset of pain, most common cause of acute painful hemiscrotum in a child, the epididymal appendage (appendix testis) is located at the head of the epididymis, <i>blue-dot sign</i> is a classic finding	Present	Nonsteroidal anti-inflammatory drugs, ice packs, and scrotal support; uncontrolled pain can be managed with surgical excision of the appendix testes

Does a History of Trauma or Presence of Fever Rule Out Testicular Torsion?

No. Some patients report the onset of torsion while playing sports or after minor trauma, and they may therefore attribute the pain to a traumatic injury. Torsion may be accompanied by fever (as well as nausea and vomiting), mimicking a gastrointestinal illness. Thus, it is critical to always examine the scrotum and testicles in adolescents with abdominal complaints.

Pathology/Pathophysiology

What Congenital Defect Predisposes Children to Developing Testicular Torsion?

Congenital defects of the processus vaginalis can lead to failure of the testes to attach to the inner lining of the scrotum,

increasing the risk of developing testicular torsion later in life. In particular, patients with *bell-clapper deformity* are at increased risk for testicular torsion. This occurs when there is a failure of normal posterior anchoring of the gubernaculum, testes, and epididymis, allowing the testes to freely rotate and swing within the tunica vaginalis of the scrotum similar to the gong (clapper) inside of a bell. This deformity is bilateral in about 50%, placing both at risk for torsion.

53 What Are Other Risk Factors for Testicular Torsion?

Other risk factors include adolescent age (rapidly growing testicle during puberty) and history of prior torsion.

How Does One Distinguish Testicular Torsion from Acute Epididymitis?

Acute epididymitis tends to occur in much older patients (mean age around 24 years vs 14 for torsion), tends to present with a more gradual onset (>24 hours), is associated with testicular swelling (less likely with torsion), is worse with standing, and is associated with dysuria.

Workup

If Suspicion for Testicular Torsion Is High, What Laboratory Tests Are Important to Obtain? What Is the Role of Additional Imaging?

Time is of the essence with testicular torsion to prevent testicular necrosis, so if clinical suspicion is high, the patient should be taken emergently to the operating room without other tests. If suspicion is low, additional workup can be considered.

If Suspicion of Testicular Torsion Is Low, What Laboratory Tests Should Be Obtained? What Imaging Is Useful?

Urinalysis should always be ordered to rule out a urinary tract infection or epididymo-orchitis, as these may also present with scrotal pain. Imaging should only be obtained with equivocal clinical findings and when imaging will not significantly delay treatment. Doppler (blood flow) ultrasound of the scrotum is the imaging modality of choice. In the presence of torsion, Doppler interrogation should demonstrate an absence of arterial blood flow in the affected testicle. The sensitivity and specificity of Doppler ultrasound in the detection of testicular torsion range from 70% to 100% and 80% to 100%,

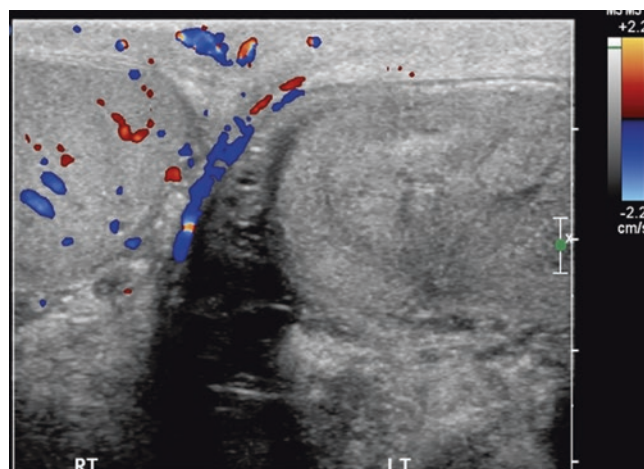


Fig. 53.2 Scrotal Doppler ultrasound showing absent flow in the left testis consistent with testicular torsion. Note: normal color flow in the right testicle (left side of image)

respectively. The ultrasound portion of the study can demonstrate other etiologies, such as a mass or evidence of trauma. Acute bleeding of testicular parenchyma appears hyperechoic, while older blood will appear hypoechoic (■ Fig. 53.2).

In the Trauma Setting, What Are the Most Important Things to Look for on Doppler Ultrasound?

To determine if the tunica albuginea is violated (testicular rupture) as this would warrant surgical repair in the acute setting. One should also confirm adequate blood flow to the testes which ensures that the vascular pedicle is intact. Since torsion often occurs during performance of sporting activities, there may be confusion as to whether the scrotal pain is from trauma or torsion. Absence of arterial flow suggests torsion or severe trauma that has disrupted the blood supply.

Management

In the Setting of Suspected Testicular Torsion, What Is the Optimal Timing from Initial Evaluation to Definitive Management?

The diagnosis of testicular torsion requires immediate surgical consultation with a urologist with a plan for emergent surgical intervention. Timing is of the utmost importance because the viability of a torsed testicle depends on how long the testicle remains torsed. One study demonstrated 100% viability when detorsion was achieved within 4–6 hours, 20% viability with detorsion after 12 hours, and 0–10% viability if detorsion was performed after 24 hours.

Is There a Role for Manual Detorsion in the Emergency Department?

Manual detorsion may be difficult due to patient pain and should not replace or delay definitive operative detorsion. However, if for some reason it is anticipated that there will be a long delay in getting to the operating room, manual detorsion may be attempted. In most cases, if the physician is facing the patient, the testis should be twisted laterally, similar to “opening a book.” Even if successful, the patient should still go to the operating room.

What Is the Surgical Treatment for Testicular Torsion?

A scrotal exploration is performed. The testicle is untwisted. If the testicle appears ischemic, the surgeon should look for return of pink color and Doppler signals within the testicle and then perform an orchiopexy (testicle sutured to scrotal wall) so as to prevent recurrence. Since patients with torsion of one testicle are at risk for torsion of the contralateral one, bilateral orchiopexy is recommended at the time of surgery.

What if the Testicle Is Necrotic at the Time of Surgical Exploration?

An orchiectomy is performed.

What Is the Recommended Management for Minor Trauma to the Testes?

Minor trauma includes cases where there is no significant swelling, pain, or breaches in the integrity of the skin around the scrotum or the tunica albuginea encasing the testis. These patients can be treated conservatively with scrotal support, ice packs, and nonsteroidal anti-inflammatory drugs.

What Are the Operative Indications for Testicular Trauma?

Operative indications include suspicion of violation of the tunica albuginea, rapidly expanding testicular hematoma, avulsion of the testicular artery, scrotal degloving, and absence of testicular blood flow as evidenced on Doppler ultrasound. With the possible exception of superficial skin lesions, most clinicians elect to explore all penetrating testicular traumas in the operating room. Surgical exploration has proven to increase testicular salvage rates and preserve fertility. Earlier surgical intervention is associated with better outcomes. Delays in management increase the risk of testicular infarction.

Prognosis

Does Loss of a Testicle from Torsion Affect Fertility?

Only one testicle is needed for fertility. In the majority of patients who lose a testicle, fertility is not affected. On occasion, testicular necrosis and loss from torsion can lead to the formation of antisperm antibodies with a subsequent decrease in sperm count and decrease in motility.

Areas Where You Can Get in Trouble

Failing to Perform a Scrotal Exam in an Adolescent Male with Abdominal Pain and Vomiting

Testicular torsion can present with nausea, vomiting, and referred abdominal pain. It is imperative that a careful scrotal exam be performed in adolescent males with this presentation.

Penile Pain After Sexual Intercourse

An erect penis can fracture during intercourse rupturing the tunica albuginea. Patients may be too embarrassed to report the history leading to the fracture but will often report a “popping” sound heard during the injury. Penile fracture is a surgical emergency and needs to be recognized promptly to undergo corporal repair. Voiding symptoms including dysuria, urinary retention (no urine since the injury), and gross hematuria are rare but need to be worked up with a retrograde urethrogram to rule out a concomitant urethral injury.

Summary of Essentials

Diagnosis

- Four cardinal signs/symptoms of testicular torsion.
 - Nausea/vomiting
 - Testicular pain duration of less than 24 hours
 - Superiorly displaced testicle
 - Absent cremasteric reflex
- High clinical suspicion is all that is needed to prompt intervention.

History and Physical

- Prehn’s sign classically negative for testicular torsion; however, this is not reliable.
- Blue-dot sign is pathognomonic for appendix testes torsion.
- Cremasteric reflex present in appendix testes torsion, absent with testicular torsion.

Pathophysiology

- Congenital defects of the processus vaginalis can lead to failure of the testes to attach to the inner lining of the scrotum.
 - Bell-clapper deformity.
- Adolescent males have rapidly growing testes during puberty, thus predisposing them to testicular torsion.

53

Workup

- When high clinical suspicion for torsion, no further work-up is necessary after history and physical exam.
- If clinical suspicion is low for torsion, urinalysis should always be ordered to rule out a urinary tract infection or epididymo-orchitis.
- Doppler ultrasound shows an absence of arterial blood flow in the affected testicle.
- In trauma setting, look for violation of tunica albuginea on ultrasound.

Management

- Presentation <6 hours; attempt manual detorsion followed by elective bilateral orchiopexy; if bedside detorsion unsuccessful, patient should be taken to the OR for detorsion.
- Presentation >6 hours; patient should be taken directly to OR for surgical detorsion and bilateral orchiopexy.
- Orchiectomy performed for necrotic testicle.

Suggested Reading

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Scrotal Mass

Areg Grigorian, Fuad F. Elkhoury, and Jeremy M. Blumberg

Case Study

A 22-year-old male presents with a left scrotal mass. He sustained mild trauma to the left hemiscrotum 5 weeks ago while playing basketball. The trauma prompted him to palpate his left testicle and he noted a left testicular mass. The patient states that he had mild pain initially that spontaneously resolved and denies any

swelling. He says the mass has remained stable in size, like a large almond, and is located “in the middle” of the left testis. He denies subjective fevers, chills, dysuria, gross hematuria, or urethral discharge. Physical examination reveals a firm 2-cm mass within the left testis. There is no pain to palpation. There are no epididymal

masses bilaterally, and the right testis is unremarkable. Abdominal exam reveals no masses and no hepatomegaly. There are no supraclavicular nodes and no gynecomastia. Laboratory analysis reveals a normal urinalysis and complete blood count.

Diagnosis

Why Is the Location of a Scrotal Mass Important to Identify?

Identifying the precise location allows for an accurate differential diagnosis based on anatomic origin (i.e., spermatic cord, epididymis, or testes).

Describe the Cause(s) of Scrotal Masses Found Involving the Skin

Table 54.1

Etiology	Features
Epidermoid or pilar cysts	Develop from epidermis or hair follicle and present as painless, slow growing, mobile, fluid-filled nodules; they occur most commonly in areas that have a lot of hair (e.g., scrotum, chest)
Squamous cell carcinoma	Proliferation of squamous cells characterized by formation of keratin pearls; presents as ulcerated, nodular mass with no telangiectasias; occurs in the fifth or sixth decade; associated with human papillomavirus and occupational exposure (soot, oil, and petroleum workers)

What Is the Differential Diagnosis of Scrotal Masses Involving the Spermatic Cord?

Table 54.2

Etiology	Features
Indirect inguinal hernia	Mass increases in size with Valsalva and emerges from internal ring, usually reducible (unless very large)
Hydrocele	Painless, unilateral scrotal mass, does not extend up spermatic cord, normal testis, transilluminates with light, due to serous fluid accumulation within tunica vaginalis
Varicocele	Feels like a “bag of worms,” more common on the left, increases in size with standing/Valsalva, does not transilluminate with light, associated with decreased sperm count and infertility

What Is the Differential Diagnosis of Scrotal Masses Involving the Epididymis?

Table 54.3

Etiology	Features
<i>Epididymitis</i>	Painful, tender epididymis, associated with urinary tract infection or sexually transmitted infection; scrotal erythema/cellulitis, positive "Prehn's sign" (relief of pain with elevation)
<i>Spermatocele</i>	Also called epididymal cyst, benign, typically painless, fluid-filled mass, cephalad and distinct from the testis, may transilluminate with light
<i>Torsion of testicular epididymal appendage (appendix testes)</i>	Most common cause of acute painful hemiscrotum in a child; the epididymal appendage (appendix testis) is located at the head of the epididymis; blue-dot sign is a classic finding; onset of pain is more gradual; cremasteric reflex is maintained

What Is the Differential Diagnosis of Scrotal Masses Found Involving the Testes?

Table 54.4

Etiology	Features
<i>Orchitis</i>	Painful, tender testicle, most often viral (mumps) but also bacterial, associated with sexually transmitted infection (in which case epididymis is also affected)
<i>Testicular torsion</i>	Sudden, severe onset of pain, testis high-riding, negative Prehn's sign (pain not alleviated with elevation), most common in pubescent males, also seen in neonates, loss of cremasteric reflex, surgical emergency
<i>Testicular cancer</i>	Presents as firm, painless testicular mass that does not transilluminate; seminoma (germ cell tumor) is the most common type

What Is the Most Likely Diagnosis for This Patient?

In a 22-year-old male with a painless, firm, non-tender testicular mass, testicular cancer is the most likely diagnosis. Despite a history of trauma, a young man (20–40 years old) with a testicular mass should be presumed to have testicular cancer until proven otherwise. Trauma to the scrotum or groin may prompt men to examine their testes leading to the discovery of an otherwise painless mass.

History and Physical

What Features on History and Physical Examination Favor the Diagnosis of Testicular Cancer?

Any painless mass within the testicle is cancer until proven otherwise. Most patients with testicular cancer present without symptoms and most are young adults (average age between 20 and 35 years). On physical exam, the mass is within the testicle (as opposed to separate from it). Rarely, patients with testicular cancer may also have gynecomastia secondary to hormonally active tumors (secreting human chorionic gonadotropin).

What Is the Implication of Constitutional Symptoms in Association with a Painless Testicular Mass?

The presence of constitutional symptoms in association with a painless testicular mass is highly suggestive of metastatic testicular cancer. Symptoms such as back or abdominal pain, weight loss, and nausea suggest retroperitoneal lymph node metastasis, whereas cough and shortness of breath suggest pulmonary metastasis.

What Risk Factors for Testicular Cancer Should Be Obtained on History?

The vast majority of patients have no risk factors. The main risk factor is cryptorchidism (undescended testicle). Other risk factors include personal history of testicular cancer (contralateral testicle), family history of testicular cancer, Klinefelter's syndrome, and white race.

What Features on Physical Examination Favor a Nonmalignant Etiology?

Masses that are bilateral, painful, mobile, and fluid-filled and that transilluminate are less likely to be cancerous.

What Are the Main Diagnoses to Consider in the Presence of a Very Painful Scrotal Mass?

Epididymitis and/or orchitis would be highest on the differential. During pubescence, testicular torsion and torsion of the appendix testis should be considered. An incarcerated hernia can be extremely painful but is separated from the testicle and epididymis.

What Benign Processes Are Typically Painless?

Spermatocele, varicocele, and hydrocele are usually painless. Careful examination will demonstrate that these masses are separated from the testicle itself.

What Physical Exam Maneuver Can Help Identify a Varicocele?

Varicoceles tend to disappear upon lying down, reappear when the patient stands up, and enlarge with Valsalva. A varicocele feels like a spongy bag of worms and is more common on the left.

Watch Out

Varicocele is associated with infertility.

Pathology/Pathophysiology

Does Cryptorchidism Increase the Risk of Developing Testicular Cancer in the Undescended Testicle, the Contralateral Descended Testicle, or Both?

Both. Testicular cancer is more likely to occur in the undescended testicle. However, in nearly 25% of patients with cryptorchidism that have testicular cancer, the contralateral descended testicle also develops testicular cancer. This suggests that an undescended testicle may not play a direct role in the development of testicular cancer, but rather, there is some other phenomenon that leads to both testicular cancer and abnormal descent of the testicles during embryologic development.

What Is the Most Common Subtype of Testicular Tumor? Is It Malignant?

Seminoma, a germ cell tumor, is the most common subtype and is considered malignant.

What Are the Major Pathologic Subtypes of Testicular Cancers?

Table 54.5

Seminomatous germ cell tumors (65%)	
Seminoma	Most common type in adults, highly responsive to radiotherapy and chemotherapy, metastasize late, excellent prognosis, normal AFP, possibly elevated β -hCG
Nonseminomatous germ cell tumors (35%)	
Embryonal carcinoma	Malignant, necrosis common, aggressive with early hematogenous spread, elevated AFP and/or β -hCG
Yolk sac	Most common type in children, malignant, elevated AFP
Choriocarcinoma	Malignant, early hematogenous spread, elevated β -hCG
Teratoma	Benign and malignant types, derived from ≥ 2 embryonic layers, elevated AFP and/or β -hCG; resistant to chemotherapy and radiation
Mixed germ cell	Benign and malignant types, multiple nonseminomatous components
Sex-cord stromal tumors	
Leydig cell	Most are benign associated with paraneoplastic syndromes (e.g., precocious puberty, hyperparathyroidism)
Sertoli cell	Most are benign often clinically silent
Other	
Lymphoma	Malignant, commonly bilateral, occurs in older males, typically diffuse large B-cell type; treat with chemotherapy

AFP alpha-fetoprotein, β -hCG human chorionic gonadotropin

What Causes Gynecomastia in Patients with Testicular Cancers?

Choriocarcinoma, a germ cell tumor, is associated with ectopic human chorionic gonadotropin (hCG) production. Elevated levels of hCG can stimulate breast development, leading to gynecomastia. It can also lead to symptoms of hyperthyroidism without a goiter, as the alpha subunit of hCG is similar to thyroid-stimulating hormone.

What Are the Differences Between Epididymitis and a Spermatocele?

Epididymitis involves an infection of the epididymis (■ Table 54.6) and is an acute process that is often confused with torsion. Patients will often complain of dysuria and a tender epididymis. Spermatoceles develop as a result of a retention cyst, often at the head of the epididymis. They are often asymptomatic but can present clinically as painless masses distinct from the testes that will transilluminate with light. In young adults, the etiology is usually related to a sexually transmitted infection. In older adults, the etiology is related to a urinary tract infection.

Why Does a Varicocele Form? Why Is It More Often on the Left? Why Does It Affect Fertility?

The pathophysiology of a varicocele relates to impaired venous drainage. Veins in the pampiniform plexus slowly and progressively dilate and enlarge over time as a result of impaired drainage. It occurs more commonly on the left as venous drainage is less optimal. The left testicular vein enters the left renal vein at a right angle and can get compressed between the superior mesenteric artery and aorta (nut-cracker phenomenon). The right testicular vein drains directly into the inferior vena cava (IVC) at a more favorable angle. Stasis of venous blood appears to increase testicular temperature, increase seminal oxidative stress, and damage sperm DNA.

■ Table 54.6 Organisms causing epididymitis

Organism	Age
<i>Chlamydia trachomatis</i> (serotypes D–K), <i>Neisseria gonorrhoeae</i>	Young adult (<35)
<i>Escherichia coli</i> , <i>Pseudomonas</i>	Older adult (>35)

Watch Out

Sudden onset of a varicocele in an adult may be caused by tumor infiltration into the IVC (right) or renal vein (left) from a renal cell carcinoma. Order a CT abdomen/pelvis.

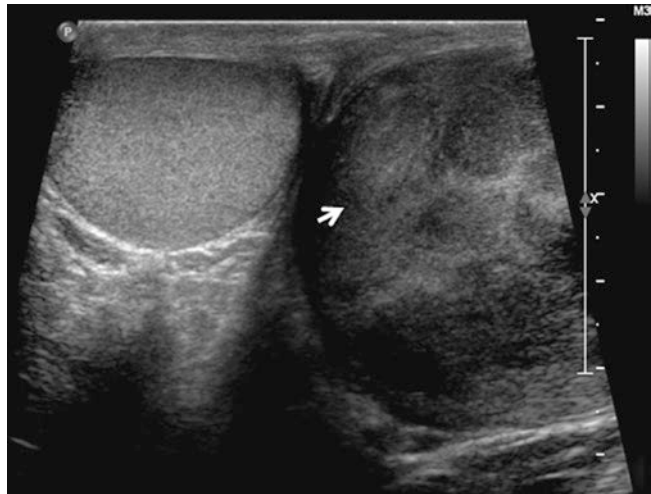
What Is the Pathophysiology of a Hydrocele?

During fetal development, the peritoneum extends into the scrotum through the inguinal canal, and the testes descend into the scrotum through this channel, called the processus vaginalis. The processus vaginalis normally closes during development, with the remaining peritoneal layer around the testes now called the tunica vaginalis. Occasionally, the processus vaginalis remains patent, resulting in peritoneal fluid flowing into the tunica vaginalis to create a *communicating* hydrocele. Hydroceles in newborns tend to resolve within the first year of life as the patent processus vaginalis closes. Unresolving communicating hydroceles require a high ligation of the patent processus vaginalis (essentially the same operation as an indirect hernia repair in an infant). In older men, hydroceles tend to be *non-communicating*, due to secretion of serous fluid from the tunica vaginalis.

Workup

What Is the Key Imaging Modality for a Patient with a Painless Testicular Mass?

Ultrasound is the best imaging. The demonstration on ultrasound of a solid mass (■ Fig. 54.1) within the testicle makes the likelihood of cancer very high, whereas a purely cystic, fluid-filled mass has a very low likelihood of being malignant. Seminomas tend to be well circumscribed and hypoechoic, whereas nonseminomas are hyperechoic with indistinct borders.



■ Fig. 54.1 Scrotal ultrasound showing an enlarged testicle with heterogeneous echotexture suggestive of infiltrative cancer. Compare with normal testis on the left of the image. White arrow: abnormal testicle

Once a Solid Testicular Mass Is Identified, What Additional Imaging Is Recommended?

Staging should then be performed with a CT scan of the abdomen and pelvis (to look for retroperitoneal lymph node metastasis) and a chest X-ray (to look for pulmonary metastasis). If retroperitoneal lymph node metastases or a pulmonary nodule is discovered, a CT of the chest should be considered. Patients with neurologic symptoms should also have a CT or MRI of the brain.

What Relevant Blood Tests Should Be Obtained in a Patient with Testicular Cancer?

There are three blood tests: AFP, β -hCG, and LDH. These should be ordered when one suspects testicular cancer, as they are used for diagnosis, staging, and prognostication. β -hCG is elevated in some seminomatous cancers and in most nonseminomatous ones, whereas AFP is *only* elevated in nonseminomatous cancer. LDH levels are useful for prognostic purposes (high levels suggest a large tumor bulk), and very high levels (along with high levels of hCG and AFP) are associated with a poor prognosis.

Is Percutaneous Biopsy for a Testicular Tumor Recommended?

No. There is a high risk of seeding, or spreading, the cancer with a biopsy.

What Are the Key Differences Between a Seminoma and Nonseminoma?

Table 54.7

	Seminoma	Nonseminoma
Incidence	Most common	Less common
Elevated AFP levels	No	Common
Elevated β -hCG levels	Rare	Common
Radical inguinal orchiectomy	Yes	Yes
Radiation therapy	Radiosensitive	Not radiosensitive
Chemotherapy	Yes	Yes
Retroperitoneal lymph node dissection	No	Yes (many patients)

AFP alpha-fetoprotein, β -hCG human chorionic gonadotropin

Management

How Is Pathologic Confirmation of Testicular Cancer Determined?

In patients with a testicular mass that is highly suspicious for malignancy (based on physical exam and ultrasound), radical inguinal orchiectomy is performed. The procedure is performed via an inguinal incision and consists of the removal of the testicle and spermatic cord up to the point where it exits from the internal ring.

Why Is an Inguinal Incision Preferred Over a Scrotal One?

Orchiectomy via a trans-scrotal incision is associated with a higher rate of local recurrence and scrotal seeding. The inguinal incision also allows a longer portion of the spermatic cord to be removed.

What Other Treatment Modalities Are Utilized After Initial Surgery for Testicular Cancer?

Radiation, chemotherapy, and retroperitoneal lymph node dissection (RPLND) are additional treatment strategies utilized. The decision as to which of these modalities to use depends on the type and stage of the cancer. For instance, seminomas are highly radiosensitive and chemosensitive, so the majority of patients receive chemotherapy or radiation therapy post-operatively. Most nonseminomas respond well to chemotherapy. RPLND is primarily recommended for nonseminomas.

What Should Be Recommended for Patients About to Undergo Orchiectomy and/or Chemotherapy?

Patients who will undergo chemotherapy may have infertility issues as a result of their treatment. Although removing one testicle should not significantly affect fertility, patients should be offered sperm banking preoperatively to afford them a better chance to have children in the future.

Does Unilateral Orchiectomy Lead to Impotence?

No. Unilateral orchiectomy does not affect erectile function. However, RPLND can injure nerves that affect ejaculatory function.

Summary of Essentials

History and Physical

- Male patients aged 20–40 with a non-tender testicular mass should raise suspicion for testicular cancer.

Pathology/Pathophysiology

- Seminoma is the most common type of testicular tumor.
- Cryptorchidism increases the risk of testicular cancer in both testicles, even the normally descended one.

Workup

- Ultrasound will show a solid mass within the testicle in testicular cancer.
- β -hCG is elevated in some seminomatous cancers and in most nonseminomatous ones, whereas AFP is only elevated in nonseminomatous cancer.

- CT of abdomen and pelvis should be used for staging.
- Biopsy is contraindicated as it may seed cancerous cells.

Management

- Radical orchiectomy is a treatment for highly suspicious testicular cancer.
- Additional therapy.
 - Radiation or chemotherapy (seminoma)
 - Chemotherapy (most testicular cancers)
 - RPLND (mostly nonseminomas)

Suggested Reading

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Blood in Urine

Jeremy M. Blumberg, Fuad F. Elkhoury, and Kiran Gollapudi

Case Study

A 68-year-old Caucasian man presents to the emergency department complaining of blood in his urine as well as small blood clots for 3 days. He denies dysuria, nocturia, urinary frequency or hesitancy, or a decreased urinary stream. He denies any fevers, chills, or weight loss. He has had similar episodes of visible blood in his urine in the last several months and has been treated twice with antibiotics for a possible urinary tract infection without improve-

ment. He has a history of hypertension for which he takes a beta-blocker; otherwise he has had no surgeries and takes no other medications. He denies any family history of malignancy or renal disease. He denies any history of trauma and does not vigorously exercise. He has a 40-pack-year history of smoking and worked as a painter. On physical exam, he is afebrile with normal vital signs. His abdomen is soft, without any palpable masses. His genitouri-

nary exam reveals a normal circumcised phallus without lesions and normal bilateral descended testicles. On digital rectal exam, his prostate is small without any nodularity, induration, or tenderness. On laboratory exam, his hematocrit is 42%, creatinine is 1.0 mg/dL, INR and PTT are normal, and prostate-specific antigen (PSA) is 2 ng/dL. His urinalysis shows a large number of red cells, no white cells, no casts, and no bacteria.

Diagnosis

What Is the Differential Diagnosis for Gross Hematuria?

Table 55.1

Condition	Comments
<i>Acute cystitis</i>	Bladder infection most commonly caused by enteric bacteria such as <i>E. coli</i> ; frequency, urgency, burning; pyuria, bacteriuria
<i>Bladder cancer</i>	Mainly urothelial carcinoma (formerly known as transitional cell carcinoma); painless hematuria; risk factors include tobacco and exposure to automobile exhaust or industrial solvents
<i>Benign prostatic hyperplasia (BPH)</i>	Obstruction of the urethra by an enlarged prostate; frequency, urgency, hesitancy, slow stream, nocturia
<i>Nephrolithiasis (kidney stones)</i>	Calcium, uric acid, cysteine, or struvite; severe pain often in the flank
<i>Benign essential hematuria</i>	Diagnosis of exclusion
<i>Prostatitis</i>	Bacterial in <35 years old and nonbacterial in older men, most commonly by urinary pathogens; fever, dysuria, perineal/back pain; avoid vigorous prostate exam
<i>Renal cancer</i>	Most common subtype is renal cell carcinoma; most are asymptomatic; small minority may present with flank pain, flank mass, and hematuria; smoking is a risk factor
<i>Pyelonephritis</i>	Mainly ascending infection of the kidney from a lower urinary tract infection; may cause systemic symptoms; costovertebral angle tenderness on percussion
<i>Prostate cancer</i>	Most common non-skin malignancy in males; diagnosed via digital rectal exam, PSA, and/or biopsy; gross hematuria is rare

Table 55.1 (Continued)

Condition	Comments
<i>Urethral stricture</i>	Similar symptoms to BPH; usually benign, caused by scarring from infection, instrumentation, trauma, or rarely cancer
<i>Trauma</i>	Injury to genitourinary tract such as traumatic Foley placement, pelvic fracture can injure bladder
<i>Polycystic kidney disease</i>	Flank pain, enlarged liver, kidney stones, hypertension; risk of subarachnoid hemorrhage (intracranial aneurysms); often positive family history
<i>Menstruation</i>	Blood can mix with the urine
<i>Pseudohematuria</i>	Due to foods or drugs
<i>Exercise induced</i>	Most commonly with running, resolves in a few days

What Are the Most Likely Diagnoses for This Patient?

The patient described above has several factors that would raise concern for urologic malignancy. These factors include that he is an elderly male, the persistence of the hematuria, the fact that the hematuria is macroscopic with clots (vs. microscopic), the absence of pain, the history of smoking, and possible exposure to carcinogenic chemicals as a painter. The absence of other urinary symptoms (hesitancy, nocturia) makes some of the more common causes of gross hematuria in elderly males (prostatitis, BPH) less likely as well. Trauma and vigorous exercise can also cause gross hematuria, but he denies this history. Furthermore, he does not have a significantly enlarged prostate on exam. There is no evidence on urinalysis of a urinary tract infection. The absence of casts or protein in the urine, combined with normal renal function, makes glomerular causes unlikely. In the absence of other significant history and laboratory anomalies, the likelihood of a urologic (kidney, ureter, bladder) malignancy is significantly increased and needs to be further investigated.

History and Physical

What Are the Differences Between Gross and Microscopic Hematuria?

Gross or macroscopic hematuria is suspected when urine is visibly pink, red, or brown or when blood clots are voided. Microscopic hematuria is discovered due to the presence of red blood cells (RBCs) or heme on urinalysis or urine dipstick. Urologic malignancy is six to seven times more common in patients with gross hematuria. A single urinalysis with ≥ 3 RBCs/HPF is sufficient to warrant a complete workup in patients with significant risk factors.

Why Is the Color and Consistency of the Urine Important?

Table 55.2	
Color/consistency	Implication
Bright red, thick consistency	Moderate or severe active bleeding
Pink	Mild active bleeding
Brown	Old blood; glomerular bleeding

Other than Blood, What Can Make Urine Appear Red?

Certain foods (beets, rhubarb) and drugs (rifampin, sulfonamides, phenazopyridine, nitrofurantoin, phenytoin, levodopa, methyl dopa, quinine, chloroquine, adriamycin, metronidazole) can have this effect (called pseudohematuria). Additionally, rhabdomyolysis—the destruction of muscle tissue, as in crush injuries—may release sufficient myoglobin into the bloodstream, and subsequently into the urine, to make the urine appear red or brown. Dark urine may also be seen in patients with elevated levels of conjugated bilirubin, as in biliary obstruction or certain metabolic diseases of the liver.

Does It Matter if Hematuria Is at the Beginning of the Urine Stream or at the End?

Yes. Hematuria present during the beginning of urine stream (*initial hematuria*) but then quickly fades away is suggestive of a urethral disease. Hematuria that appears near the end of the urine stream (*terminal hematuria*) is suggestive of bladder or prostate pathology. If the hematuria is present from beginning to end (*total hematuria*), then the kidneys or ureters are most likely involved.

What Is the Importance of Pain in Association with Hematuria?

Pain in association with hematuria strongly suggests infection or urinary obstruction. As such, urinary tract infection, prostatitis, pyelonephritis, and nephrolithiasis would be higher on the differential.

What Is the Classic Presentation for Nephrolithiasis?

Ureteral stones present with acute colicky flank pain that may extend into the groin area if the stone is close to the bladder. The pain is described as colicky, with periods of severe pain during which the patient will not be able to stay still and will shift positions in an attempt to relieve their pain, followed by temporary resolution of the pain. This tendency to move around can help differentiate these patients from those with peritonitis as the latter prefer to remain rigid. Patients with nephrolithiasis may also complain of nausea, vomiting, and dysuria.

What Are the Risk Factors for Nephrolithiasis?

Prior episodes of nephrolithiasis, family history, high protein diet, males > females, low fluid intake, dehydration, recurrent urinary tract infections, diabetes, gout, renal tubular acidosis, electrolyte abnormalities (e.g., hypercalcemia), and certain medications (e.g., acetazolamide, furosemide, allopurinol).

What Are the Most Common Symptoms/Presentation for Kidney Cancer? What Is the Classic Presentation?

In most patients, renal cancer is discovered incidentally as a mass on imaging for other complaints. The classic triad is flank pain, abdominal mass, and hematuria, but this is seen in only 10–15% of patients. Rarely, a sudden onset of a varicocele suggestive of tumor infiltrating into the inferior vena cava or left renal vein may be the only clue.

What Are the Main Risk Factors for Renal Cancer?

Smoking, male gender, older age, obesity, family history, and exposure to certain heavy metals and chemicals.

What Is the Most Common Presentation for Bladder Cancer? What Are the Risk Factors?

Painless gross hematuria. A minority of patients will have urinary symptoms. Similar to renal cancer, risk factors include smoking, male gender, older age, family history, and exposure to heavy metals and chemicals. In addition, chronic bladder irritation and inflammation (from recurrent urinary tract infections, indwelling Foley, pelvic irradiation) increase the risk.

What Is the Most Common Presentation for Prostate Cancer? What Are the Risk Factors?

Most prostate cancers are discovered incidentally because of PSA screening. On occasion, patients may present with urinary symptoms similar to BPH. With metastatic disease, the patient may present with bone pain, obstructive renal failure, or weight loss. The main risk factors are age >50 years, black race, high fat diet, and family history.

Anatomy

What Comprises the Urinary Tract and Where Along the Tract Can Bleeding Arise?

The kidneys, ureters, bladder, and urethra make up the urinary tract. The kidneys and ureters make up the *upper* urinary tract, while the bladder and urethra comprise the *lower* urinary tract. Bleeding can arise from anywhere along the tract, from the glomerulus to the distal urethra.

Pathology/Pathophysiology

What Is the Difference Between Glomerular and Non-glomerular Hematuria? Why Is It Important to Distinguish Them?

Glomerular hematuria implies that the blood is coming from the kidney itself. The most common causes include IgA nephropathy (Berger's disease), thin glomerular basement membrane disease, and hereditary nephritis (Alport's syndrome). Non-glomerular causes can originate from the upper (kidney, ureter) or lower (bladder, urethra) urinary tract. Glomerular causes are within the purview of nephrologists, whereas non-glomerular causes concern the urologist.

Kidney Stones

Where Do Renal Stones Develop and in What Circumstances Do They Lead to Symptoms?

Stones can develop anywhere in the urinary tract but typically originate from the kidney or the renal pelvis. Many of these stones (<5 mm) will pass freely into the bladder and eventually exit the body during micturition. Stones do not cause symptoms unless they get lodged somewhere in the urinary tract and cause obstruction. The most common locations for a stone to get stuck are at points of narrowing in the genitourinary tract: (1) the ureteropelvic junction, (2) where the ureter crosses the iliac vessels, and (3) the ureterovesical junction.

Why Do High Protein Diets Increase the Risk of Developing Renal Stones?

Breakdown of protein (e.g., fish, red meat, chicken) lowers the urinary pH and increases excretion of uric acid which can contribute to the formation of stones. Decreasing dietary protein, oxalate, and sodium intake decreases the risk of developing renal calculi.

What Is the Most Common Type of Renal Stone and What Is the Leading Cause of This Type of Stone?

The most common renal stone (■ Table 55.3) is calcium oxalate. The leading cause of calcium oxalate renal stones is hypercalciuria (■ Fig. 55.1).

■ Table 55.3 Renal stones

Type	Etiology	Radiology	Features
Calcium oxalate	Hypercalciuria, Crohn's	Radiopaque	Most common type
Struvite	Urinary tract infection secondary to urease + organism (e.g., <i>Proteus</i> , <i>Klebsiella</i>)	Radiopaque	Women affected more can form staghorn calculi (outlining renal pelvis)
Calcium phosphate	Renal tubular acidosis, hyperparathyroidism	Radiopaque	Can form more readily in alkalinized urine
Uric acid	Low urinary pH, gout, chemotherapy, patients with ileostomy	Radiolucent	Can be treated by increased urinary pH (e.g., alkalinizing agents)



■ Fig. 55.1 Abdominal X-ray showing branching radiopaque stones outlining the renal collecting system, consistent with staghorn calculi

Renal Cancer

What Is the Most Common Type of Kidney Cancer?

Renal cell carcinoma (RCC) is the most common primary tumor of the kidney. RCC arises from the renal tubule cells, and nearly 1/3 of patients have metastatic disease at the time of presentation. The most common histologic subtypes include clear cell (70%), papillary (15%), and chromophobe (5%).

Where Is the Most Common Location for RCC Metastasis?

The lung, though RCC is known to metastasize to many different organs. The most common tumor to metastasize to the thyroid is RCC.

What Genetic Syndromes Are Associated with RCC?

Most cases of RCC are sporadic, but several familial syndromes are associated with RCC. These syndromes include von Hippel-Lindau (autosomal dominant, mutation of chromosome 3p), tuberous sclerosis (autosomal dominant, mutation of chromosome 9), and Birt-Hogg-Dube (autosomal dominant, mutation of chromosome 17).

What Paraneoplastic Syndromes Are Associated with RCC?

■ Table 55.4

Paraneoplastic syndromes	Mediator
Polycythemia	Increased erythropoietin production
Hypercalcemia	PTH-like hormone production
Hypertension	Increased renin production
Cushing's syndrome	Ectopic cortisol production
Stauffer's syndrome	Reversible liver dysfunction; ↑ALP, ↑GGT, ↑ESR; hepatosplenomegaly; unknown mechanism

PTH parathyroid hormone, *ALP* alkaline phosphatase, *GGT* gamma-glutamyl transferase, *ESR* erythrocyte sedimentation rate

Bladder Cancer

What Is the Most Common Type of Bladder Cancer?

The most common type of bladder cancer is urothelial cell carcinoma (UCC), formerly referred to as transitional cell carcinoma. UCC can arise from the renal collecting system, ureters, bladder, or urethra. UCCs are graded as either low grade or high grade. They are staged based on the depth of their invasion.

Prostate Cancer

What Is the Most Common Type of Prostate Cancer?

Prostatic adenocarcinoma.

Workup

What Is the First Step in the Workup of a Patient with Gross Hematuria?

The first step is to perform a urinalysis to confirm that there are, in fact, red blood cells in the urine. The urinary dipstick method (■ Table 55.5) detects hemoglobin in the urine. False-positive results can result from myoglobinuria (e.g., muscle breakdown secondary to intense exercise, rhabdomyolysis) or from solutions such as iodine that can cross-react with the dipstick indicator.

■ Table 55.5 Urine dipstick

Dipstick tests	Implications
<i>pH</i>	>7.0 may indicate <i>Proteus mirabilis</i> (urea-splitting) infection
<i>Specific gravity</i>	Proportional to urine osmolality; appropriate changes to volume status indicate adequate renal concentrating ability
<i>Protein</i>	Proteinuria indicative of glomerular dysfunction
<i>Glucose</i>	Excessive glucose indicative of diabetes
<i>Blood</i>	Hematuria
<i>Ketones</i>	Present in DKA
<i>Nitrite</i>	Suggests presence of bacteria and UTI
<i>Leukocyte esterase</i>	Suggests presence of WBC and UTI
<i>DKA</i> diabetic ketoacidosis, <i>UTI</i> urinary tract infection, <i>WBC</i> white blood cells	

What Is the Next Step in the Workup?

A positive dipstick analysis should be confirmed with a microscopic urinalysis. This analysis will provide the number of RBCs/HPF, the number of WBCs, and the presence of bacteria. In addition, the presence of crystals can be determined. Furthermore, the presence of dysmorphic RBCs and red blood cell casts suggests a glomerular source of bleeding.

Watch Out

Patients who give a history of gross hematuria should undergo a hematuria workup even if they do not have a positive urine dipstick or urinalysis.

What Additional Laboratory Tests Should Be Ordered During the Hematuria Workup?

■ Table 55.6

Lab tests	Why order?
<i>Complete blood count</i>	White blood cell count if concerned about infection
	Hemoglobin to determine if anemic from hematuria
	Platelet count may reveal thrombocytopenia
<i>Metabolic panel</i>	BUN and creatinine to evaluate renal function

■ Table 55.6 (Continued)

Lab tests	Why order?
<i>PT/PTT/INR</i>	Rule out coagulopathy
<i>PSA</i>	Screen for prostate cancer in appropriate patients, can also be elevated in setting of urinary tract infection or recent instrumentation
<i>Urine culture</i>	Rule out infection
<i>Urine cytology</i>	Rule out urothelial malignancy

How Does the Urinalysis Help Distinguish Between a Glomerular and a Non-glomerular Cause of Hematuria?

Urinary findings suggestive of a glomerular source for hematuria include brown-colored urine, red cell casts, dysmorphic red blood cells, and significant proteinuria. If the hematuria is thought to be of glomerular origin, the patient should be referred to a nephrologist.

What Workup Is Recommended for Non-glomerular Hematuria?

For non-glomerular hematuria, the workup depends on whether the hematuria is symptomatic or asymptomatic and whether the hematuria is microscopic or gross.

What Workup Is Recommended for Symptomatic Non-glomerular Microscopic Hematuria?

This is most often associated with stones and infection. If the urinalysis demonstrates a urinary tract infection, appropriate antibiotic coverage is recommended. If there is no evidence of infection, kidney stones may be suspected.

What Is the Best Diagnostic Test for Nephrolithiasis?

The test of choice is a non-contrast helical CT scan (CT-KUB) since it can detect the majority of stones and is more accurate than X-ray or sonogram. Ultrasonography is the procedure of choice in pregnant women and women of childbearing age, though stones are poorly visualized by ultrasound.

Watch Out

Non-contrast helical CT scans can be misleading in patients with HIV. Antiretroviral drugs (e.g., indinavir) can result in small radiolucent stones that can be missed. In such patients, a contrast-enhanced CT scan is more beneficial as it can show a filling defect at the location of these stones.

What Further Workup Is Recommended in the Presence of Gross Hematuria?

The strongest predictors for cancer are age over 50 and a history of gross (macroscopic) hematuria. As such, the majority of patients who present with gross hematuria should undergo a workup for malignancy. The workup consists of a CT urogram, urine cytology, and cystourethroscopy (for bladder and urethral pathology). CT urogram consists of non-contrast study (for urolithiasis), nephrogenic (for renal masses), and excretory phases (for urothelial lesions). Further workup is dictated based on the findings from these studies.

Does Negative Urine Cytology Rule Out a Malignancy?

No. A urine cytology detects abnormal-appearing urothelial cells that are concerning for a urothelial carcinoma of the bladder. The higher the tumor grade, the more likely urine cytology will be positive. The sensitivity of urine cytology for low-grade tumors is less than 50%. Also, in the presence of significant hematuria, cytopathologic analysis may not be able to pick up abnormal cells in the background of a significant number of RBCs.

Management

What Is the Guiding Treatment Principle for Hematuria?

Hematuria is managed by identifying and treating the underlying cause.

Renal Stones

What Is the Best Management for Nephrolithiasis? How Does the Size of the Stone Change Management?

Renal stones that are <5 mm are likely to pass on their own and should be managed with supportive therapy unless the patient is septic, has a solitary kidney, or has uncontrolled pain. Alpha-blockers such as tamsulosin can also be given to relax the ureteral wall. Stones between 5 and 9 mm should be

managed using clinical judgment. Stones larger than 9 mm are unlikely to pass spontaneously and will therefore require more invasive treatment.

What Are the Emergent Surgical Indications for Renal Stones?

Obstructive stones that lead to urosepsis, intractable pain, progressive renal damage, or a solitary kidney (i.e., the patient only has one functional kidney) require ureteral stent placement or percutaneous nephrostomy tube placement.

Renal Masses

What Are the Treatment Options for Renal Masses Concerning for RCC?

Renal masses that are concerning for RCC are treated either with radical or partial nephrectomy depending on the size and location of the mass. In patients with small masses, or who are poor surgical candidates, surveillance and thermal or cryoablation are also options.

What Is a Radical Nephrectomy?

A radical nephrectomy is the removal of the kidney, perinephric fat, Gerota's fascia, ureter, lymph nodes, and, possibly, ipsilateral adrenal gland. However, in most cases, the ipsilateral adrenal gland can be preserved.

Bladder Cancer

How Is Urothelial Cell Carcinoma of the Bladder Treated?

UCC is initially treated with transurethral resection for diagnosis and staging. Small superficial tumors can be treated with complete transurethral resection and potentially intravesical chemotherapy (mitomycin) or immunotherapy (bacillus Calmette-Guérin [BCG] infused via urinary catheter). UCC has a high recurrence rate, and patients need to be closely monitored. The standard of care for nonmetastatic tumors that invade the detrusor muscle is radical cystectomy with urinary diversion.

Watch Out

BCG is also used as a vaccine against tuberculosis in other countries but not the United States.

What Is a Radical Cystectomy?

Radical cystectomy involves the removal of the entire bladder and pelvic lymph nodes. In a male, the prostate and seminal vesicles are also removed. In a female, the cervix, uterus, fallopian tubes, and part of the vagina are also removed.

Prostate Cancer

What Is a Radical Prostatectomy? Which Patients Are Appropriate Candidates for This Procedure?

Removal of the prostate and seminal vesicles. Patients with disease contained to the prostate and a life expectancy of at least 10 years are good candidates.

What Are Nonsurgical Treatments for Prostate Cancer?

External beam radiation, brachytherapy (placement of radioactive beads within the prostate), and androgen deprivation therapy. Patients who are poor surgical candidates or who have reduced life expectancy due to some other cause may receive nonsurgical therapy or active surveillance.

Special Circumstances

What Are the Next Steps in Management if Significant Hematuria Persists Despite Foley Catheter Placement and Manual Irrigation?

If the patient continues to have significant hematuria after manual irrigation, a three-way Foley catheter can be placed, and continuous bladder irrigation can be initiated. Continuous irrigation helps prevent the formation of new blood clots and also decreases exposure of potential bleeding sites in the lower urinary tract to urokinase. Urokinase is a serine protease that is present in urine that activates plasmin and the thrombolytic cascade. If hematuria does not improve or resolve with bladder irrigation, the patient may be taken to the operating room for cystoscopy. Cystoscopy allows for adequate clot evacuation, diagnosis of lower urinary tract pathology, and fulguration (i.e., electrical cauterization) of bleeding sites.

When Should a Patient Be Admitted to the Hospital for Gross Hematuria?

The majority of patients with gross hematuria can be evaluated and treated in a non-emergent outpatient setting. A patient with significant and symptomatic gross hematuria should be admitted for inpatient management. The color and consistency of the urine, blood clots, and urinary retention may point to significant hematuria but are not absolute indications for admission. Active bleeding despite adequate bladder irrigation and symptomatic anemia are two indications for inpatient admission and workup.

Areas You Can Get into Trouble

Not Placing a Foley Catheter in the Setting of Significant Gross Hematuria

A Foley catheter should be placed if the patient has significant gross hematuria or blood clots. Failure to do so may result in urinary retention due to obstruction from the blood clots. All of the blood clots should be manually irrigated out of the bladder with a catheter tip syringe with either sterile saline or water. When hematuria is secondary to urethral or prostatic trauma, a Foley catheter can act to tamponade bleeding sites.

Placing a Foley Catheter in the Setting of Trauma and Blood at the Urethral Meatus

A Foley catheter should not be placed in the setting of trauma (such as pelvic fracture) when blood is noted at the urethral meatus, as this represents a potential urethral injury. The Foley may convert a partial injury into a complete transection. A retrograde urethrogram (RUG) must be performed to rule out an injury if there is any indication of urethral injury (blood at the urethral meatus, high-riding prostate, open-book pelvic fracture). Additionally, all patients with signs of traumatic spinal cord injury should have a Foley catheter placed as they have a high incidence of urinary retention.

Can Cross Hematuria Be Associated with an Abdominal Aortic Aneurysm (AAA)?

Yes, an AAA can rupture into the inferior vena cava forming an aortocaval fistula or into the iliac veins leading to venous congestion of retroperitoneal organs, including the kidneys and bladder, and present with gross hematuria. The patient would present with sudden onset of back pain, hypotension, tachycardia, as well as swelling of the lower extremities and high-output congestive heart failure.

Summary of Essentials

History and Physical

- Pain with hematuria suggests urinary tract infection or urinary obstruction.
- Painless gross hematuria raises suspicion for malignancy (especially in the elderly).
- Inquire about risk factors for malignancy.

Pathology/Pathophysiology

- Gross hematuria: urine that is visibly red, pink, or brown.
- Microscopic hematuria: urine appears normal but RBCs are detected on urinalysis.
- Pseudohematuria: red urine (without RBCs) due to certain foods, drugs, or metabolic disorders.
- RCC is usually asymptomatic and is usually discovered incidentally.
- Bladder cancer usually presents as painless gross hematuria.
- Prostate cancer is usually discovered by PSA screening and prostate biopsy.
 - Adenocarcinoma is the most common.
- Kidney stone: calcium oxalate is the most common.

Workup

- Urine dipstick (for blood, protein), microscopic urinalysis.
 - Dysmorphic RBCs or RBC casts suggest a glomerular cause:
 - Glomerular causes are treated medically by a nephrologist.
 - Non-glomerular causes are often treated by a urologist.
- Suspected kidney stone: non-contrast CT; in women of childbearing age and children, ultrasonography should be used instead.
- Most kidney stones are radiopaque (visible on X-ray).
- Gross hematuria (especially if > 50 years old)—malignancy workup:
 - CT urogram

- Urine cytology
- Cystourethroscopy

Management

- Kidney stones
 - <5 mm: will likely pass spontaneously
 - 5–9 mm: management individualized
 - >10 mm: extracorporeal shock wave lithotripsy, percutaneous nephrostomy, ureteroscopy, or rarely nephrolithotomy
- Renal cancer
 - Partial or radical nephrectomy
- Bladder cancer
 - Transurethral resection, infusion of mitomycin or BCG, or radical cystectomy
- Prostate cancer
 - External beam radiation, brachytherapy, androgen deprivation therapy, radical prostatectomy, or active surveillance

Suggested Reading

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Question Set: Urology

Questions

1. A 26-year-old man that recently emigrated from Sudan to the United States arrives to your office complaining of red urine. He does not experience any pain but says that for the last week his urine has appeared red. He also reports night sweats, fevers, and losing 10 lbs over the last 2 months without a change in his appetite. Cystoscopy is performed, and biopsies are taken of a tumor that appears nodular with a plaque-like and irregular surface. What is most likely to be seen on microscopic analysis?
- (A) Urothelial carcinoma (transitional cell carcinoma)
 - (B) Squamous cell carcinoma
 - (C) Adenocarcinoma
 - (D) Mucinous (colloid) carcinoma
 - (E) Small cell carcinoma
2. A 7-year-old boy presents to the doctor with a non-tender scrotal mass. His vitals are normal, and he has no complaints. His mother reports that he has been behaving more aggressively at home and has gotten into two fights at school over the past month. Physical examination reveals a firm 2.5-cm mass within the right testicle. There are no epididymal masses bilaterally, although both testicles appear to be enlarged. He also has axillary hair. Laboratory analysis reveals a normal urinalysis. What is the most likely etiology of the testicular mass?
- (A) Leydig cell tumor
 - (B) Sertoli cell tumor
 - (C) Seminoma
 - (D) Teratoma
 - (E) Juvenile granulosa cell tumor
3. A male infant presents with a mass in his scrotum that has been present since birth. His mother states that the mass changes in size when the infant cries and does not seem to be painful. On exam, the mass appears to be adjacent to his testicle which is palpated posteriorly. The mass is soft and non-tender and transilluminates. There is no bulge or mass at the internal ring. What is the most appropriate next step in the management?
- (A) Surgical management
 - (B) Medical management
 - (C) Ultrasound
 - (D) Needle aspiration
 - (E) Reassurance
4. A 50-year-old man arrives to the emergency department with severe acute colicky flank pain and hematuria. The patient has a long-standing history of gout. Which of the following is true regarding the type of kidney stone the patient likely has?
- (A) Most are radiopaque.
 - (B) They are often seen in patients with hyperparathyroidism.
 - (C) Shock wave lithotripsy is not helpful.
 - (D) Sodium bicarbonate administration is beneficial.
 - (E) Suppressive antibiotics are helpful in prevention.
5. A 20-year-old male presents with a right testicular mass. He noticed the mass after getting kneed in the groin during a basketball game 3 weeks earlier. He states that the mass is not tender. He denies any other symptoms. On physical examination, there is a firm

2-cm mass within the right testicle. Ultrasound confirms a 2-cm homogeneous mass within the right testicle. CT scan of the abdomen and pelvis is negative. Chest X-ray is negative. Which of the following is the most appropriate next step in management?

- (A) Radical inguinal orchiectomy
- (B) Scrotal orchiectomy
- (C) Fine needle aspiration
- (D) Open testicular biopsy
- (E) Percutaneous biopsy

6. A 78-year-old man arrives to the emergency department with colicky flank pain for the past 4 days that is now accompanied by nausea, vomiting, fever, and hematuria. Past medical history is significant for congestive heart failure and prior myocardial infarction. On physical examination, the patient has a blood pressure of 100/60 mmHg, temperature of 38.0 °C, and a heart rate of 110/min. Urinalysis reveals 150 RBC/hpf and 20 WBC/hpf. Laboratory tests demonstrate a WBC of $15 \times 10^3/\mu\text{L}$ (normal $4.1\text{--}10.9 \times 10^3/\mu\text{L}$) with 10% bands. Imaging demonstrates a 10-millimeter stone lodged in the ureterovesical junction with dilation of the right renal calyx. Broad-spectrum antibiotics are administered intravenously. What is the best next step in management?
- (A) Percutaneous nephrostomy tube
 - (B) Open nephrostomy
 - (C) Shock wave lithotripsy
 - (D) Placement of a ureteral stent
 - (E) Admit to ICU for close monitoring
7. A 45-year-old male presents with a new scrotal mass on the right side that he noticed a week earlier. It is non-tender. He reports no history of trauma. When the patient is standing, the scrotal mass is separate from the testicle and epididymis, feels like a "bag of worms," and is soft, compressible, and non-tender. With the patient supine, the mass is unchanged. The left side is normal. What is the most appropriate next step in the management?
- (A) Scrotal support and NSAIDs
 - (B) Surgical intervention
 - (C) CT of the abdomen
 - (D) Reassurance and observation
 - (E) Ultrasound-guided biopsy of the mass
8. A 15-year-old boy arrives to the emergency department 4 hours after experiencing a sudden onset of right testicular pain while playing soccer. He does not recall any specific trauma to his testicle during the game. He also reports nausea and vomiting. Physical examination reveals a tender and swollen right testicle that is displaced superiorly. The testicle appears to be lying transversely. He has an absent cremasteric reflex on the right. The left testicle is normal in location and is non-tender. What is the next step in management?
- (A) Ultrasound
 - (B) Color Doppler ultrasound
 - (C) Right orchiopexy
 - (D) Bilateral orchiopexy
 - (E) Scrotal support and nonsteroidal anti-inflammatory drugs
9. A 37-year-old obese woman arrives to the emergency department with left flank pain and hematuria. She has never experienced these symptoms before. Her past medical history includes Crohn's which has been controlled with mesalamine. She is afebrile with a blood pressure of 130/84 mmHg and a pulse of 104/min. Physical examination reveals a laparotomy scar in her right lower quadrant. She is given analgesics for pain control. What is the most likely etiology of her acute symptoms?
- (A) Gallstones
 - (B) Hypercalciuria
 - (C) Increased absorption of oxalate
 - (D) Urease-producing bacteria
 - (E) Mesalamine

10. A 10-year-old boy presents to his doctor for follow-up 2 weeks after having an upper respiratory tract infection (URI). He complains of pain in his scrotum. It has been bothering him for the past 3 days but is more painful today. A scrotal ultrasound demonstrates an enlarged and rounded epididymis. His scrotal skin appears thickened. What other finding(s) would you suspect in this patient's history and physical?
- (A) Skin lesions and abdominal pain
 - (B) Recent weight loss, night sweats, and fevers
 - (C) Recent epididymitis
 - (D) Sores in the mouth and swelling of the eyes
 - (E) Painful urination
11. An infant is found to have an undescended left testicle shortly after birth. During his 6-month checkup, the left testicle remains undescended. What can be done to decrease this patient's risk of developing testicular cancer later in life to match that of a boy born without cryptorchidism?
- (A) Immediate orchiopexy
 - (B) Orchiopexy within the next 6 months
 - (C) Hormonal therapy
 - (D) Observation until age 2 and then orchiopexy
 - (E) Risk cannot be decreased to that of a boy without cryptorchidism
12. A 52-year-old male is brought to the hospital by his wife with complaints of intense pain that started around his right flank and now radiates to his right groin. He said that his urine appears pink. He appears to be in severe pain and is unable to remain still during examination. His abdominal exam is unremarkable. Urinalysis reveals 100 RBC/hpf. IV fluids and analgesics are administered. Which of the following is the most appropriate imaging?
- (A) Helical CT scan of the abdomen and pelvis without contrast
 - (B) Helical CT scan of the abdomen and pelvis with contrast
 - (C) Upright abdominal X-ray
 - (D) Intravenous pyelogram (IVP)
 - (E) Renal ultrasound
13. A 30-year-old male restrained driver is involved in a high-speed motor vehicle accident. In the emergency department, he has a strong odor of alcohol. Blood pressure is 120/70 mmHg and heart rate is 80/min. His abdomen appears distended and mildly tender diffusely. The pelvis is stable. On rectal exam, the prostate feels normal. There is no blood at the urethral meatus. On insertion of a Foley catheter, there is gross hematuria. CT scan of the abdomen and pelvis with oral and IV contrast reveals a large amount of free fluid and contrast in the peritoneum. The liver and spleen appear to be normal as does the pelvis. What part of the genitourinary tract is most likely injured?
- (A) Ureter
 - (B) Base of the bladder
 - (C) Bladder dome
 - (D) Renal hilum
 - (E) Urethra
14. A 14-year-old boy is diagnosed with a varicocele by his family physician. Which of the following is true about this condition?
- (A) It affects either side with similar frequency.
 - (B) It causes the testicle to ride high in the scrotum.
 - (C) It transilluminates on physical exam.
 - (D) It is related to impaired venous drainage.
 - (E) It is associated with an absent cremasteric reflex.
15. A 32-year-old newlywed man presents to the emergency department with intense pain in his penis. He reports having an accident falling in the bathroom. His temperature is 37.7 °C, blood pressure is 126/80 mmHg, and pulse is 110/min. His physical

examination is significant for a blue discoloration at the base of a swollen and deviated penis. He has no ulcers or discharge. Retrograde urethrogram did not identify any urethral injuries. What is the best next step for this patient?

- (A) Abdominal and pelvic CT scan
- (B) Cystoscopy
- (C) Analgesics and bed rest
- (D) Surgical repair
- (E) Temporary suprapubic catheter

Answers

✓ 1. Answer B

The most common type of bladder cancer in the United States is urothelial carcinoma (transitional cell carcinoma) and is well known to be associated with environmental carcinogens such as smoking and polycyclic aromatic hydrocarbons (A). However, in parts of the world that are endemic for schistosomiasis, such as Sudan, Egypt, and Tanzania, the most common variant is squamous cell carcinoma. The chronic granulomatous cystitis secondary to the parasite can result in squamous metaplasia and subsequent development of squamous cell carcinoma. Adenocarcinoma of the bladder is rare in the developed world (C). Mucinous carcinoma is a subtype of adenocarcinoma and is characterized by abundant extracellular mucin (D). Small cell carcinoma is often considered a subtype of urothelial carcinoma that is accompanied by small cell differentiation (E).

✓ 2. Answer A

Leydig cell tumors are benign sex cord-stromal tumors that are associated with high levels of androgen production that may result in *precocious puberty* in young boys. These children can behave more aggressively and develop early secondary sexual characteristic changes such as enlarged testicles, scrotum, and/or penis and accelerated linear growth. Characteristic rod-shaped Reinke crystals may be seen on histology for Leydig cell tumors. Scrotal ultrasound would be the next diagnostic step as this can help visualize the mass in question and is also important to help evaluate the contralateral testicle. Ultrasound might also help distinguish between benign lesions, which are more often hyperechoic, and solid lesions that are more likely to be malignant and appear hypoechoic. Sertoli cell tumors are benign and often clinically silent (B). Seminoma, a germ cell tumor, is the most common type and is considered malignant (C). Teratomas can be benign or malignant, are derived from ≥ 2 embryonic layers, and are associated with AFP or hCG production (D). Granulosa cell tumor is far more common in females and thus is associated most frequently with ovarian cancer (E).

✓ 3. Answer E

A hydrocele is a fluid collection within the processus and/or tunica vaginalis of the scrotum. *Communicating hydroceles* develop as a result of a failed closure of the processus vaginalis during embryologic development, allowing for peritoneal fluid to enter the scrotum. *Non-communicating hydroceles* have no connection to the peritoneum, and fluid accumulation develops from the mesothelial lining of the tunica vaginalis. The majority of infants born with hydroceles will have spontaneous resolution by the time they are 1 year old; thus, reassurance and observation are the most appropriate forms of management. Surgical repair is not typically done unless the hydrocele is persistent past the first year of life (A). There are no available medical therapies for managing hydroceles (B). There is no indication for ultrasound with this classic presentation (C). Hydroceles are sometimes confused with hernias; however, ultrasound is neither sensitive nor specific for distinguishing the two. Ultrasound would be more suitable for ruling out malignancy in a young adult with a testicular mass. There is no role for needle aspiration (D).

- ✓ 4. Answer D
The most likely diagnosis in a patient with a past medical history significant for gout presenting with acute colicky pain and hematuria is nephrolithiasis secondary to uric acid renal stones. Unlike other types of renal stones, this type is radiolucent and will not show up on X-ray (A). Patients with gout are at increased risk for developing uric acid stones. Sodium bicarbonate will alkalinize the urine to achieve a urinary pH of 6–6.5, as this would provide optimal conditions for dissolution of uric acid stones. Patients with hyperparathyroidism are more prone to developing calcium oxalate renal stones (B). Suppressive antibiotics should be considered in the case of struvite stones secondary to recurrent urinary tract infections (E). Shock wave lithotripsy may be added as an adjunct to urine alkalinization to further improve the stone-free rate (C).
- ✓ 5. Answer A
The demonstration on ultrasound of a solid mass (e.g., homogeneous) within the testicle makes the likelihood of cancer very high. Any painless mass within the testicle is cancer until proven otherwise. Most patients with testicular cancer present without symptoms, and most are young adults (average age between 20 and 35 years). Trauma to the scrotum or groin may prompt men to examine their testes leading to the discovery of an otherwise painless mass. In patients with a testicular mass that is highly suspicious for malignancy (based on physical exam and ultrasound), radical inguinal orchiectomy is performed. Orchiectomy via a trans-scrotal incision is associated with a higher rate of local recurrence with scrotal seeding (B). The inguinal incision also allows a longer portion of the spermatic cord to be removed. There is no role for biopsy as there is a high risk of seeding or spreading the cancer with biopsy (C–E).
- ✓ 6. Answer A
Ureteral obstruction in association with sepsis requires *emergent* urinary decompression. This is most expeditiously achieved via a percutaneous nephrostomy tube. Shock wave lithotripsy is unlikely to relieve the obstruction caused by a stone of this size (C). Open nephrostomy is rarely indicated (B). Close monitoring in the ICU as the sole management plan would be inappropriate for a patient with sepsis secondary to a blocked ureter (E). Hydration, analgesics, and bed rest would be appropriate for an uncomplicated and small renal stone without accompanying hydronephrosis. A ureteral stent is an option; however, it is a more time-consuming procedure that will not be as expeditious in a septic patient compared to a percutaneous nephrostomy (D).
- ✓ 7. Answer C
A scrotal mass that feels like a “bag of worms” is the classic description for a varicocele, which essentially represents dilated veins in the pampiniform plexus. Sudden onset of a right-sided varicocele should raise suspicion for a renal cell carcinoma that has occluded the inferior vena cava (IVC). The vast majority (80%) of varicoceles are left sided due to the higher likelihood of impaired drainage of the left testicular vein (it enters the left renal vein at a right angle). Drainage of the right testicular vein is better as it enters at a less acute angle and directly into the IVC. Thus, sudden onset of a right-sided varicocele raises suspicion that the IVC is obstructed. The best initial test is to perform a CT scan of the abdomen to look for a renal or other retroperitoneal mass. There is no known effective medical management for varicoceles, so scrotal support and NSAIDs would not be recommended (A). Varicoceles are associated with infertility (due to low sperm count and decreased motility). Surgical intervention is considered for such an indication (B). Reassurance and observation would not be appropriate as further workup is indicated (D). Since a varicocele is a nest of dilated veins, attempts to biopsy would be contraindicated (E).
- ✓ 8. Answer D
The history and physical are classic for testicular torsion, including the age (adolescent), sudden onset of pain, testicular swelling, superior displacement of the testicle, and an absent cremasteric reflex. Constitutional symptoms (nausea and vomiting) are also common. Testicular torsion represents an emergency, as time is of essence. If a testicular

torsion is reduced within 6 hours of onset, there is a very high testicular salvage rate (>90%), whereas with delays in management beyond 24 hours, the testicular salvage rate plummets to <10%. If the diagnosis is in doubt, color duplex scan (ultrasound with Doppler) is recommended to look for the absence of blood flow in the affected testicle but would be inappropriate in a patient with a clear-cut presentation as it would delay management (B). Ultrasound is not helpful as it does not provide blood flow information (A). Treatment is surgical, via orchiopexy. Since the contralateral testicle is at risk, bilateral orchiopexy is recommended (C). Scrotal support and NSAIDs would be inappropriate (E).

✓ 9. Answer C

Patients with Crohn's that present with flank pain and hematuria should raise suspicion for nephrolithiasis secondary to hyperoxaluria. Her laparotomy scar suggests that she had an ileocolic resection, which would predispose her to fat malabsorption as the terminal ileum is the principal site for fat absorption. In healthy patients, intraluminal calcium binds to oxalate to prevent its reabsorption from the GI tract. In patients with increased amounts of fat in the GI lumen (e.g., Crohn's status-post ileocolic resection), the calcium preferentially binds to fat leaving the unbound oxalate available for reabsorption and, thus, increases the risk of developing calcium oxalate renal stones. Hypercalciuria would have been the most likely etiology had she not had Crohn's (B). Urease-producing bacteria are associated with struvite stones and recurrent urinary tract infections (D). Gallstones do not cause flank pain or hematuria, and mesalamine is not a known risk factor for the development of renal stones (A, E).

✓ 10. Answer A

This patient's history and ultrasound findings are suggestive of Henoch-Schönlein purpura (HSP). This classically develops after an URI or drug exposure (e.g., vancomycin) in young children. HSP is typically characterized by nonthrombocytopenic purpura, arthralgia, abdominal pain, intussusception, and, less frequently, scrotal pain. Rarely, scrotal pain may be the only manifestation of HSP. The sonographic findings of an enlarged, rounded epididymis are sufficiently characteristic to allow distinction from torsion in most cases. HSP patients may also develop *thickened scrotal skin*. Recent weight loss, night sweats, and fevers can represent the constitutional symptoms seen in patients with testicular cancer (B). However, these patients present with a painless testicular mass. A young boy with no history of sexual activity would not be expected to have epididymitis or a urethral tract infection with painful urination (C, E). Sores in the mouth and swelling of the eyes are seen in patients with Behçet's syndrome, a form of vasculitis (D). Patients with Behçet's can also develop scrotal pain secondary to open sores. However, Behçet's is very rare in the United States and more commonly seen in the Middle East and Asia.

✓ 11. Answer E

Infants born with cryptorchidism have an increased risk of developing testicular cancer later in life. An undescended testicle may be palpable, high up in the inguinal canal, or nonpalpable, in which case it may be in the retroperitoneum or absent. Orchiopexy is a procedure to move an undescended testicle into the scrotum and anchor it to the scrotal wall. Orchiopexy has several theoretical benefits. It may improve fertility. An undescended testicle is thought to increase the risk of infertility, as the warmer environment of the retroperitoneum or the inguinal canal leads to impairment of germ cell maturation. Undescended testicles are at higher risk of torsion. Orchiopexy prevents such a catastrophic event. Orchiopexy permits regular physical examination so as to detect any potential malignancies later in life. However, the act of lowering the testicle does not lower its future risk of developing a malignancy (thus answers A–D are incorrect). The higher the testicle is found away from the scrotum, the higher the likelihood of developing testicular cancer later in life. Although the precise time to perform orchiopexy is not well established, most clinicians elect to do it shortly after the patient's first year of life so as to reduce the risk of infertility. Hormonal therapy with intramuscular beta-hCG injection is sometimes used in an attempt to induce testicular descent; however, it is successful in only a minority of patients.

✓ 12. Answer A

The presentation is consistent with nephrolithiasis. Initial management should focus on IV fluid hydration and analgesia. Recommended imaging includes a KUB (a supine X-ray of the abdomen) and a *non-contrast* CT of the abdomen and pelvis. The use of contrast may interfere with visualization of the stone (B). An upright abdominal X-ray is used to look for air-fluid levels in association with a small bowel obstruction or free air under the diaphragm (C). Such a film cuts off the pelvis and as such will miss many ureteral stones. IVP has largely been replaced by CT (D). Renal ultrasound may be used in pregnant patients but may miss stones; it is also used to look for hydronephrosis as an adjunct to KUB (if a CT scan is not obtained) (E).

✓ 13. Answer C

Injuries to the genitourinary tract are commonly seen following blunt trauma. Bladder injuries typically occur when the bladder is full (such as following a drinking binge). Injuries to the bladder are divided into intraperitoneal and extraperitoneal. Intraperitoneal injuries will demonstrate a large amount of intraperitoneal free fluid (and contrast) on CT scan. Although the free fluid might initially be thought of as being blood, the absence of liver or spleen injury raises suspicion that the fluid is urine. Intraperitoneal injuries require laparotomy and repair. The bladder dome is the only region covered by the peritoneum and is considered the weakest portion. Thus, it is the only portion prone to rupture in the peritoneum and lead to *chemical peritonitis*. However, the most common overall location of bladder rupture is at the base of the bladder, which is located in the retroperitoneum and will not present with peritonitis (B). Retroperitoneal bladder injuries are most often associated with pelvic fractures and can be managed nonoperatively with a Foley catheter. The ureter and renal hilum are also located in the retroperitoneum (A, D). Urethral injury is associated with blood at the urethral meatus and would not be expected to cause free fluid in the peritoneum (E).

✓ 14. Answer D

Varicocele is often an asymptomatic condition, but patients may complain of a vague discomfort and/or pain in the scrotum. The affected side will have a mass that feels similar to a “bag of worms” and will disappear upon lying down and reappear when the patient stands up. Varicoceles develop as a result of tortuous dilation of the pampiniform plexus of the veins surrounding the spermatic cord and testis. About 80% occur on the left side (A). Since it is a venous drainage problem, varicoceles increase in size with Valsalva. Unlike a hydrocele that transilluminates (as it contains clear fluid), a varicocele does not (C). A testicle that is high in the scrotum would raise concern for testicular torsion (if associated with sudden pain) or a partially undescended testicle (B). An absent cremasteric reflex is seen with testicular torsion (E).

✓ 15. Answer D

The history of sudden penile pain following trauma combined with the physical examination is consistent with a penile fracture, which requires urgent surgical repair. It is due to a tear in the tunica albuginea with subsequent rupture of one or both of the corpus cavernosum. Failure to recognize and surgically manage the injury often results in permanent erectile dysfunction. Men are often embarrassed to describe the true nature of the injury, so they fabricate stories that don't fit the clinical picture. Penile fractures most often occur during vigorous sexual activity. Most patients describe a “snapping” sound preceding the fracture. A hematoma rapidly develops within the corpus cavernosum and presents as a blue discoloration at the base of the penis, which is deviated at the fracture site. Prior to surgical exploration, a urethral injury should be ruled out with a retrograde urethrogram. CT scan and cystoscopy play no role in the evaluation of penile fractures (A–B). Analgesics and best rest are not acceptable options for a patient suspected of having a penile fracture (C). Temporary suprapubic catheter would not help address the underlying problem (E).

Vascular

Christian de Virgilio

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Transient Loss of Vision in the Right Eye

Areg Grigorian, Jessica Beth O'Connell, and Christian de Virgilio

Case Study

A 60-year-old male presents with an episode of vision loss in his right eye. The event occurred a week ago, while he was watching television, and resolved spontaneously after about 20 minutes. He described it as a curtain or shade that descended over his eye from top to bottom. He denied having any pain in the eye. He also denied any headaches, tiredness in his jaw while chewing, or any generalized fatigue. He denied any episodes of weakness or numbness on one side of his body or changes in his speech. He has a 30-pack-year history of smoking. He also has a history of hypertension and hypercholesterolemia. He denied a history of coronary artery disease or diabetes. He takes a beta-blocker and a statin. Physical examination reveals a systolic blood pressure of 140/70 mmHg. He has normal carotid pulses with a right carotid bruit. Neurologic examination is normal.

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Diagnosis**What Is the Differential Diagnosis for Transient Monocular Vision Loss?**

■ Table 56.1

Category	Conditions
Circulatory	<i>Embolus</i> from the carotid artery
	<i>Central retinal artery occlusion</i> with cherry red spot on funduscopy
	<i>Severe orthostatic hypotension</i> ; seen in diabetics
	<i>Giant cell arteritis</i> ; jaw claudication, headaches, and increased erythrocyte sedimentation rate (ESR)
	<i>Retinal vein occlusion</i> ; associated with chronic glaucoma, diabetes, and coagulopathy; patients report painless, monocular “cloudy vision,” and funduscopy shows cotton wool spots, edema, and retinal hemorrhages
Ocular	<i>Retinal detachment</i> ; floaters
	<i>Open-angle glaucoma</i> ; gradual loss of vision (from peripheral to central)
Neurologic	<i>Papilledema</i> ; associated with increased cerebral pressures (e.g., malignant hypertension, pseudotumor cerebri), headache, and bilateral disk swelling
	<i>Optic neuritis</i> ; associated with multiple sclerosis, inflammation of the optic nerve, painful visual loss
	<i>Retinal migraine or aura</i> ; result of vasospasm; painful vision loss

What Is the Most Likely Diagnosis for This Patient?

Transient loss of vision, without other associated symptoms (such as headache, eye pain, floaters, and jaw tiredness when chewing), in a smoker with a carotid bruit is most likely due to atherosclerotic plaque from the internal carotid artery (ICA).

History and Physical Examination**What Is the Term for the Eye Symptom the Patient Describes?**

Amaurosis fugax is derived from Greek (amaurosis meaning darkness) and Latin (fugax meaning fleeting). The term describes transient vision loss and is described as a “curtain” or “shade” descending the field of vision in one eye. It is often the result of atherosclerotic debris from a plaque in the ICA that embolizes to the ophthalmic artery (the first branch of the ICA in the brain), leading to temporary ipsilateral retinal ischemia that typically lasts for minutes.

In a Patient with This Eye Symptom, What Finding on Fundoscopic Ophthalmologic Examination Would Support a Carotid Artery Source of the Symptom?

Hollenhorst plaques may be seen. These are cholesterol microemboli seen within the retinal arterioles that have a bright, yellow, and refractile appearance. They are considered highly suggestive of embolization from a plaque at the carotid bifurcation.

What if the Patient Instead Described Transient Motor and Sensory Loss of the Left Arm and Leg, What Term Would Be Used for Such a Symptom?

A hemispheric TIA (transient ischemic attack). This is a focal neurologic deficit that lasts <24 hours, though the vast majority lasts 30 minutes or less.

How Does One Distinguish a TIA from a Stroke?

The symptoms of a stroke persist >24 hours. Since most TIAs last less than an hour, symptoms lasting beyond that time are highly suggestive of a stroke.

What Does a Carotid Bruit Signify?

It is indicative of turbulent flow, most often due to a hemodynamically significant stenosis of the internal carotid artery due to atherosclerosis. The turbulent flow causes the artery distal to the stenosis to vibrate.

What Else Can Cause a Bruit in the Neck?

Other causes include a murmur transmitted from the heart to the neck, such as from aortic stenosis (such a murmur will typically be louder when auscultated at the left sternal border as compared to the neck, and intensity will decrease with Valsalva), stenosis of the external carotid artery (considered a benign problem), and stenosis of the subclavian artery (can cause subclavian steal syndrome).

What Is Subclavian Steal Syndrome?

Subclavian steal syndrome is classically associated with stenosis of the left subclavian artery proximal to the vertebral artery branch point, leading to left arm tiredness (claudication) with exercise. Blood then flows retrograde through that vertebral artery into the arm, stealing blood from the posterior brain. Patients report transient vertigo, dizziness, and less commonly syncope, during arm exercise.

Are Dizziness, Syncope, and Headaches Considered Symptoms of Carotid Stenosis?

No. Rarely, bilateral carotid stenosis can lead to syncope secondary to cerebral hypoperfusion. Dizziness and syncope may be symptoms of disease in the posterior circulation of the brain.

What Are the Risk Factors for Carotid Stenosis?

The risk factors for carotid stenosis are older age, male gender, hypertension, smoking, hypercholesterolemia, diabetes, and obesity.

Anatomy

How Do You Distinguish Between the ICA and External Carotid Artery (ECA) in the Neck?

The ICA has no branches in the neck.

What Are the Branches of the ECA?

The branches of the external carotid artery can be remembered with “some attendings like freaking out potential medical students”: superior thyroid, ascending pharyngeal, lingual, facial, occipital, posterior auricular, and maxillary arteries.

What Is the First Branch of the Internal Carotid Artery?

The first branch is intracranial and is the ophthalmic artery.

What Is the Classic Anterior Circulation Ischemic Stroke in Terms of Arterial Distribution and Symptoms?

An anterior circulation ischemic stroke (■ Table 56.2) is the most common type (70% of cases) of stroke. The cortex is supplied by branches of the two internal carotid arteries and

■ Table 56.2 Anterior circulation

Artery	Branches from	Supplies	Presentation with ischemia
Ophthalmic artery	Internal carotid artery	Retina	Ipsilateral amaurosis fugax; patients report sudden onset of painless loss of vision
Anterior cerebral artery	Internal carotid artery	Medial surfaces of the frontal and parietal lobes, corpus callosum, anterior portions of the basal ganglia, and internal capsule	Contralateral and greater motor and sensory loss in the lower extremities than upper extremities, gait apraxia
Middle cerebral artery	Internal carotid artery	Lateral frontal, parietal, and superior temporal lobes, insula, claustrum, internal capsule	Contralateral and greater motor and sensory loss of the upper extremities than the lower extremities, gaze palsy, aphasia, the <i>most common form</i> of anterior circulation ischemic stroke

two vertebral arteries. The anterior cerebral artery (ACA) and the middle cerebral artery (MCA), both of which branch from the internal carotid, connect with the posterior cerebral artery (derived from the basilar artery) to form the circle of Willis. The MCA primarily supplies the lateral surface of the frontal, parietal, and superior temporal lobes. The deeper branches supply the basal ganglia and internal capsule. An occlusion of the MCA is the most common location for an anterior circulation stroke, resulting in contralateral spastic paralysis/weakness, gaze palsy, and aphasia.

Why Is It Important to Distinguish Between Anterior and Posterior Circulation Symptoms?

Carotid plaques embolize to the anterior circulation, most often to the middle cerebral and less commonly into the anterior cerebral artery, thus causing anterior circulation symptoms. If the patient's symptoms are related to posterior circulation ischemia, then a carotid plaque should not be implicated as the source of the ischemia, and, therefore, carotid endarterectomy would not be beneficial.

Pathophysiology

What Are the Two Main Causes of Stroke?

Strokes are broadly categorized into ischemic and hemorrhagic types. Ischemic stroke (most common, about 85%) occurs when there is a blockage to the blood supply to the brain, whereas hemorrhagic stroke occurs when an artery ruptures and bleeds. The main causes of ischemic strokes are emboli (clot from somewhere else) and thrombosis (clot forming within the intracranial arteries). Causes of hemorrhagic stroke include *intracerebral* hemorrhage due to poorly controlled hypertension, trauma, congenital arteriovenous malformations, and *subarachnoid* hemorrhage due to a ruptured intracranial aneurysm.

Watch Out

Uncontrolled hypertension is a strong risk factor for both ischemic and hemorrhagic strokes.

What Are the Main Sources of Cerebral Emboli?

Emboli arise from the rupture of plaque in the ICA at the carotid bifurcation and from the heart (left atrial thrombus in association with atrial fibrillation, mural thrombus in association with acute myocardial infarction, endocarditis). Less commonly, plaque from the aortic arch can embolize.

Watch Out

If a patient presents with a TIA or stroke in association with a deep vein thrombosis, consider *paradoxical embolus*, which travels from the vein to the right heart, across a patent foramen ovale to the left heart, and then to the carotid artery.

What Is a Lacunar Stroke?

A lacunar stroke is an ischemic stroke that is caused by an occlusion of the deep penetrating arteries. The main risks are severe hypertension and diabetes. Lacunar infarcts are not generally thought to be due to large vessel (carotid) or cardiac embolization. Lacunar strokes involve deep brain structures such as the basal ganglia, internal capsule, and thalamus.

How Is an Atherosclerotic Plaque Formed?

The initiating event leading to plaque formation is believed to be endothelial damage. Damaged vessel walls release thrombin, adenosine diphosphate, and cytokines stimulating platelet migration. This initiates a cascade of events ultimately leading to smooth muscle proliferation and fibroplasia resulting in a narrowed vessel.

Why Does Atherosclerotic Plaque Localize at the Bifurcation of the Carotid Artery?

Atherosclerotic plaque has a predilection for developing at arterial bifurcations. Bifurcations cause alterations in blood flow. Specifically, it alters the shear stress (forces) applied to the arterial intima. High shear stress (seen at the *inner* wall or flow divider of bifurcations) is healthy for the intima, whereas low shear stress (seen in *outer* walls) promotes plaque buildup. Additionally, blood flow in the outer wall of a bifurcation has areas of transient reversal of flow with stasis of blood. This transient reversal of blood flow coupled with the low shear stress within the region promotes conditions favorable for additional plaque buildup at the outer walls.

Watch Out

Low shear stress promotes atherosclerotic plaque buildup.

How Does a Carotid Stenosis Typically Cause Symptoms?

The symptoms from a carotid stenosis are the result of atherosclerotic emboli from the ICA at the carotid bifurcation embolizing distally into the brain. Symptoms are usually *not* due to a reduction in blood flow from a hemodynamic

significant stenosis, as the other carotid and vertebral arteries provide adequate collateral blood flow via the circle of Willis.

Is the Degree of ICA Stenosis Related to the Risk of Symptoms Developing?

As the atherosclerotic burden increases, the risk of developing symptoms increases. Larger plaques are more unstable and prone to rupture leading to a greater chance of distal embolization.

If a Patient Had Multiple TIAs, with the Same Symptom Each Time, What Is the Most Likely Source of the TIA?

The carotid artery would be the most likely source. Blood flows in concentric laminar rings. Particles that enter the bloodstream at the same point location consistently lodge distally at the same terminal branch point. Thus, emboli originating from an internal carotid plaque will likely travel in the same direction each time, producing the same neurologic deficit consistently. In contrast, emboli from a cardiac source (e.g., atrial fibrillation) can travel anywhere in the systemic circulation and result in a variety of conditions ranging from stroke to limb ischemia to bowel ischemia.

What Happens When the Internal Carotid Artery Occludes?

The internal carotid artery typically occludes at its origin at the bifurcation in the neck. Since there are no branches in the neck, clot often propagates up into the brain. Depending on collateral blood flow, the clot may stop just before the ophthalmic artery or progress into the ACA or MCA. Thus, the occlusion may cause no symptoms, a TIA, or a stroke. Collateral blood flow is supplied by the circle of Willis.

What Is a Symptomatic Carotid Artery Stenosis?

A symptomatic carotid artery stenosis is one in which plaque from the carotid bifurcation is thought to be the source of emboli to the brain resulting in a TIA or a stroke within the anterior circulation. So classically, a carotid stenosis would be considered symptomatic if it results in ipsilateral amaurosis fugax with contralateral weakness/paralysis/numbness (transient, TIA or permanent, stroke).

What Additional Symptom Can Help Differentiate Left from Right Carotid Artery Stenosis?

Since Broca's area is in the left cerebral hemisphere, a stenosis of the left ICA can result in aphasia.

Workup

How Useful Is the Presence of a Bruit for Detecting Carotid Artery Stenosis?

The sensitivity and specificity of auscultation in detecting carotid artery stenosis are about 60 and 98%, respectively. Because of the low sensitivity, physical examination is not sufficient in ruling out the carotid artery as the source of stroke.

What Is the Diagnostic Test of Choice for the Workup of Possible Carotid Stenosis?

Carotid duplex scan is the first step in working up carotid stenosis. This noninvasive tool uses ultrasonography to visualize the plaque and Doppler to measure the rise in velocity of blood flow at the narrowed segment, which is proportional to the degree of stenosis.

Are Additional Diagnostic Studies Warranted?

Carotid duplex is somewhat operator dependent and provides a range of % stenosis (0–49%, 50–69%, 70–99%, occluded). Most surgeons obtain a second study to confirm the exact percent of the ICA stenosis, either via CTA or MRA (■ Fig. 56.1). Formal angiogram is rarely used due to cost, invasiveness, and its risk of causing a stroke (the catheter that is inserted into the carotid artery may break off plaque).



■ Fig. 56.1 Lateral CT angiogram showing high-grade stenosis at the origin of the internal carotid artery (white arrow)

Management

What Are the Three Management Options for Symptomatic Carotid Stenosis?

The three management options for symptomatic carotid stenosis are medical management alone (aspirin {ASA}, clopidogrel, and statin), carotid endarterectomy (CEA), and carotid artery stenting (CAS).

What Are the Determinants of Which Option to Choose?

Whether the patient is symptomatic or asymptomatic, the severity of the stenosis, the patient's surgical risk, and whether the stenosis is surgically accessible from a neck incision are the determinants of which option to choose.

At What Percent of ICA Stenosis Should CEA Be Considered in Symptomatic Patients?

Benefit is greatest in symptomatic patients with high-grade (70–99%) stenosis. Benefit is greater (a) with hemispheric symptoms than amaurosis fugax, (b) in men than women, and (c) with increasing degree of stenosis. Refer to

■ Table 56.3.

Following a Stroke or TIA, What Is the Optimal Timing of CEA?

CEA should optimally be performed within 2 weeks. The greatest risk of another embolic event is within that time frame. As such, the benefit of CEA is greatest within this time period. The longer one waits, the greater the risk of another embolic stroke, thus obviating the benefit of CEA.

■ Table 56.3 Management of carotid stenosis in a symptomatic patient

Degree of stenosis	Management
100%	Aspirin, statin, and/or clopidogrel
70–99%	CEA
50–69%	CEA is of less benefit (more benefit in men and if symptoms are hemispheric; no benefit in women and if symptom is amaurosis fugax)
<49%	Aspirin, statin, and/or clopidogrel

Why Is CEA Not Recommended for a Symptomatic Patient with an Occluded (100% Stenosis) ICA?

Once the ICA occludes, there is no further flow in the artery and therefore no future risk of embolization and stroke. If one were to attempt CEA, one would find an occluded artery with no flow and clot extending all the way up into the brain.

What Is the Role of CEA in a Patient with Symptomatic ICA Stenosis that Resulted in a Stroke that Has Caused Complete Paralysis of the Arm and Leg As Well As Aphasia?

There is no role for CEA in a patient following a stroke that causes severe neurologic deficits (complete hemiplegia). The goal of CEA is to protect the remaining viable motor and language regions, so as to prevent further damage. With complete hemiplegia and aphasia, there is essentially no further viable motor cortex to protect, and thus the risks of surgery outweigh the benefits.

What Is the Anticipated Stroke Risk Reduction for CEA for a Symptomatic 70–99% ICA Stenosis?

For a 70–99% stenosis, CEA plus ASA (as compared with ASA alone) lowers the stroke rate at 2 years from 26% to 9%.

What Is the Management of Carotid Stenosis in an Asymptomatic Patient?

■ Table 56.4

Degree of stenosis	Management
100%	Aspirin, statin, and/or clopidogrel
60–99%	CEA for men, medical management for women
<59%	Aspirin, statin, and/or clopidogrel
CEA carotid endarterectomy, ASA aspirin	

At What Percent of ICA Stenosis Should CEA Be Considered in Asymptomatic Patients?

Benefit is greatest in asymptomatic patients with 80–99% stenosis. Benefit is greater (a) in men vs women and (b) with increasing degree of stenosis. Although there is benefit from

CEA if ICA stenosis is >60%, most recommend CEA only if there is >80–99% stenosis.

What Is the Anticipated Stroke Risk Reduction for CEA for an Asymptomatic 60–99% ICA Stenosis?

CEA reduces stroke at 5 years from 11% to 5% (or annually from about 2% to 1%).

Watch Out

The benefits of CEA vs medical management in symptomatic and asymptomatic carotid diseased patients and their reported stroke reduction percentages are highlighted in two studies: North American Symptomatic Carotid Endarterectomy Trial (NASCET) (1991) and Asymptomatic Carotid Atherosclerosis Study (ACAS) (1995). Read these studies if you plan to rotate on vascular surgery.

Why Is There Less Benefit from CEA in Women?

The data suggests that women are more likely to have unfavorable outcomes, such as surgical mortality, neurologic morbidity, and recurrent stenosis. This is likely a reflection of the fact that women have smaller caliber vessels putting them at risk for developing recurrent stenosis and perioperative carotid thrombosis.

What Three Drugs Have Been Shown to Reduce the Risk of Perioperative Stroke After CEA?

Perioperative aspirin, clopidogrel, and statin.

Watch Out

Not only do statins lower serum cholesterol level, they also stabilize atherosclerotic plaque to prevent rupture and embolus (pleiotropic effect).

Why Is Blood Pressure Control Important Prior to CEA?

Poorly controlled blood pressure has been shown to increase the risk of perioperative stroke. In addition, the manipula-

tion of the carotid artery (and carotid sinus) during CEA is associated with baroreceptor dysfunction.

What Complication Likely Occurred in a Patient Complaining of a Severe Headache Days After CEA?

This is concerning for *cerebral hyperperfusion syndrome* and occurs in 1% of CEA patients about 2–7 days after surgery. It is thought to occur as a result of impaired autoregulation of cerebral blood flow from long-standing stenosis of the carotid artery resulting in a compensatory dilation of distal cerebral vessels to maintain adequate cerebral blood flow. Once the carotid stenosis is repaired, autoregulation is not able to immediately adjust to the sudden increase in blood flow. Patients complain of a severe frontal headache, possibly followed by seizures and, rarely, intracerebral hemorrhage.

What Cranial Nerves Are at Risk of Injury During CEA?

Table 56.5

Cranial nerve	Presentation
VII (<i>marginal mandibular branch</i>)	Droop in the corner of the mouth
IX (<i>glossopharyngeal nerve</i>)	Difficulty in swallowing
X (<i>vagus nerve</i>)	Hoarseness due to recurrent laryngeal nerve coming off distal to injury
XI (<i>spinal accessory nerve</i>)	Diminished or absent function of the sternocleidomastoid or trapezius muscles
XII (<i>hypoglossal nerve</i>)	Tongue deviation to the side of injury

Watch Out

The most common cranial nerve injury following CEA is to the hypoglossal nerve (tongue deviation to side of injury), followed by injury to the recurrent laryngeal nerve (hoarseness).

What Is an Acceptable Risk of Stroke/Death Following CEA?

The acceptable risk of stroke/death following CEA is <3% for asymptomatic CEA and <6% for symptomatic CEA.

Area Where You Can Get in Trouble

New Neurologic Deficit in the Postoperative Recovery Room After CEA

New neurologic deficits (weakness of extremity, asymmetric smile) occurring within the first 12 hours after CEA are concerning for thromboembolic phenomena or a residual intimal flap at the repair site. The patient should immediately be given systemic heparin and taken back to the operating room for exploration (do not waste time with imaging).

Area of Controversy

Carotid Stenting Versus CEA for Symptomatic High-Grade (>70%) ICA Stenosis

CEA has been the standard for invasive treatment of ICA stenosis. However, carotid artery stenting (CAS) has evolved as a less invasive alternative, initially developed for patients deemed to be at high surgical risk. The advantages of CAS include the ability to be performed under local anesthesia, no neck incision, minimal risk of nerve injuries, and lower risk of perioperative myocardial infarction. Recent consensus is that CAS has a higher risk of perioperative stroke as compared to CEA. As such, CAS is not recommended for asymptomatic ICA stenosis, where the benefit of intervention is already less than symptomatic patients. CAS is more applicable for patients with symptomatic ICA stenosis who have a hostile neck (previous neck surgery, neck irradiation, lesion high in neck) that would make CEA more difficult or for those at high risk for general anesthesia.

Summary of Essentials

Differential Diagnosis

- Amaurosis fugax differential diagnosis includes carotid embolus, central retinal artery occlusion, giant cell arteritis, retinal vein occlusion, retinal detachment, papilledema, and optic neuritis

History

- TIA <24 hours, stroke >24 hours
- More common in men and smokers
- Classic carotid stenosis symptoms: (1) amaurosis fugax (ipsilateral) and (2) arm and leg weakness/numbness (contralateral) +/- aphasia (left carotid 99% of time)
- Dizziness, syncope, and headaches *are not* typical carotid symptoms
- Stroke: the fourth leading cause of death in the United States

Physical Exam

- Hollenhorst plaques (emboli to the retina on fundoscopic exam)
- Carotid bruit is specific but not sensitive

Pathology/Pathophysiology

- Low shear stress promotes atherosclerotic plaque formation
- ICA causes neurologic symptoms secondary to embolization of atherosclerotic debris to the anterior circulation (middle cerebral, anterior cerebral arteries)
- Anterior circulation ischemic stroke is the most common type (70%)
- Posterior circulation ischemic stroke not from carotid disease (most often from cardiac embolus)
- Carotid stenosis is a marker for coronary artery disease
- The most common cause of death in patients with carotid stenosis is myocardial infarction

Workup

- Carotid duplex to determine % ICA stenosis
- Confirmatory imaging recommended (CTA or MRA)

Management

- CEA
 - Greatest benefit for symptomatic 70–99% ICA stenosis
 - Less benefit for symptomatic 50–69% ICA stenosis
 - Less benefit for asymptomatic 60–99% ICA stenosis
 - No benefit for <50% ICA stenosis
- Carotid stenting
 - Higher risk of stroke than CEA (less risk of perioperative MI)
 - Best used for symptomatic ICA stenosis with high cardiac risk or hostile neck (radiated, prior surgery)
 - Not indicated for asymptomatic ICA stenosis

Suggested Reading

- Barnett HJ, Taylor DW, Eliasziw M, et al. Benefit of carotid endarterectomy in patients with symptomatic moderate or severe stenosis. North American Symptomatic Carotid Endarterectomy Trial Collaborators. *N Engl J Med.* 1998;339(20):1415–25.
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Right Calf Pain with Walking

Divya Ramakrishnan and Christian de Virgilio

Case Study

A 65-year-old male presents with a 5-month history of progressively worsening right calf pain upon walking. He describes the pain as a tightening or cramping, and it comes on after walking two blocks. The pain forces him to stop walking and is relieved after he sits down for 5 minutes. The pain comes on consistently at the same two-block walking distance each time, unless he walks fast or uphill, in which case he can walk much less.

He denies waking up at night with pain in his foot. He reports a 40-pack-year smoking history and is taking antihypertensives. He has normal 2+ femoral pulses bilaterally; nonpalpable (0) popliteal, dorsalis pedis, and posterior tibial pulses on the right side; and diminished (1+) popliteal, dorsalis pedis, and posterior tibial pulses on the left. He is moderately obese, yet both legs appear to be thin. The skin on his lower legs

appears thin and shiny, flaky, and dry, with no hair. His toenails are thickened. There are no ulcers in his feet. Capillary refill is diminished in his right foot at 4 seconds (normal ≤ 2 seconds). Laboratory values reveal a total cholesterol of 280 mg/dL (normal < 200 mg/dL), low-density lipoprotein (LDL) of 160 mg/dL (65–180 mg/dL), and a high-density lipoprotein (HDL) of 35 mg/dL (> 35 mg/dL).

Diagnosis

What Is in the Differential Diagnosis?

Table 57.1

Disease	Pathophysiology	Symptoms
Peripheral arterial disease	Atherosclerotic plaque obstructing blood flow	Pain with walking
		Relieved with a few minutes of rest
		Reproducible at the same walking distance
Osteoarthritis of the hip or knee	Mechanical degeneration of joint structures	Not relieved with a few minutes of rest
		Not reproducible at the same walking distance
Spinal stenosis	Narrowing of the spaces of the vertebral column causing nerve root compression (neurogenic claudication)	Generalized weakness of both legs that worsen with walking
		Relieved by leaning forward
Sciatica	Irritation or compression of the sciatic nerve	Buttock pain, leg pain “shooting” down the posterior thigh
Chronic venous stasis	Incompetence of vein valves, pooling of blood in the legs	Worse after prolonged standing (end of the day)
		Leg swelling
		Relieved by elevating legs and wearing compression stockings

What Is the Most Likely Diagnosis?

In a patient with a long-standing smoking history, hypertension, and a 5-month history of progressively worsening and reproducible right calf pain with exercise, the most likely diagnosis is claudication secondary to peripheral arterial disease (PAD). In addition, his physical exam (thin, flaky, dry, hairless legs) and diminished pulses are consistent with the diagnosis.

History and Physical

What Is Claudication, and What Is the Three-Part Definition that Should Be Obtained by History?

Claudication derives from the Latin word *claudicare* and means “to limp.” It is caused by a reduction in blood flow to the leg muscles, most commonly by an atherosclerotic plaque. It is not typically due to a blood clot or embolization. The reduced arterial blood supply cannot meet the metabolic demand of the muscles utilized during walking. The diagnosis can readily be suspected based on the three-part definition obtained by history: (1) pain in the leg with walking, (2) relieved within a few minutes of rest, and (3) reproducible at the same walking distance each time.

Claudication Is a Symptom of What Underlying Disease?

Claudication is a symptom of peripheral arterial disease (PAD). PAD most often affects the lower extremities and less commonly the upper extremities and the intestinal and renal arteries. It is usually caused by atherosclerosis. It leads to a gradual slowly developing reduction in blood flow in the extremities (chronic limb ischemia).

What Are the Main Risk Factors for PAD?

Modifiable risk factors for PAD include smoking, obesity, sedentary lifestyle, hypertension, diabetes, and hypercholesterolemia.

Table 57.2 The Rutherford classification system

Category	Patient presentation
0	Asymptomatic
1	Mild claudication
2	Moderate claudication
3	Severe claudication
4	Ischemic rest pain
5	Minor tissue loss
6	Major tissue loss

Non-modifiable risk factors for PAD include advanced age, male gender, and family history of cardiovascular disease.

What Is the Spectrum of Severity in PAD?

The spectrum of severity is categorized by the Rutherford classification of chronic limb ischemia (Table 57.2).

What Is Ischemic Rest Pain, and How Does It Present?

Ischemic rest pain is a sign of advanced PAD (Rutherford class 4). It typically presents in the foot, most commonly in the toes (as that is the distal most part of the limb, where the blood has the hardest time reaching). It occurs at night when the patient is lying supine, as the arterial blood flow is so poor that gravity is needed to get blood to the foot. The patient wakes up with the toes aching or feeling numb and is forced to get up and either walk around or dangle the painful leg over the edge of the bed. In advanced stages, the patient has to actually sleep using an inclined bed or in a chair to keep the painful foot in a dependent position.

Watch Out

Always ask about rest pain, as the presence of rest pain identifies a patient as having limb-threatening ischemia. Ask the patient specifically if they ever wake up at night with pain in their foot and what they do to relieve it (such as dangle the foot over the edge of the bed or get out of bed). Rest pain can be confused with diabetic neuropathy. Neuropathic pain tends to be burning in nature, involves the whole foot (both feet usually), and is not relieved by dependency.

What Is Buerger's Sign?

It is a physical examination sign of advanced chronic ischemia. The affected foot turns pale after it is elevated (usually

for 2 minutes). Once the patient sits up and dangles the foot down, it becomes ruborous (like a cooked lobster) due to marked arteriolar dilation from chronic severe ischemia that causes a reactive hyperemia. Patients with ischemic rest pain typically will manifest Buerger's sign. Such patients will also have multiple levels of arterial obstruction and an accompanying low ankle-brachial index (ABI) of <0.4 . The absence of Buerger's sign makes ischemic rest pain very unlikely.

Watch Out

Do not confuse Buerger's sign with Buerger's disease (thromboangiitis obliterans), which presents with cyanotic and blue digits typically in young male smokers.

What Is the Differential Diagnosis of Ischemic Rest Pain?

Table 57.3

Disease	Pathophysiology	Symptoms/signs
Ischemic rest pain	Severe multilevel PAD; ABI <0.4	Awaken at night with pain in the forefoot
		Relieved by standing or dangling feet
		Dependent rubor
Diabetic neuropathy	Neural damage and conduction defects leading to sensory, motor, and autonomic nerve dysfunction	Bilateral burning in feet
		Not relieved by dependency
		Stocking-glove distribution
		No rubor
Night cramps	Idiopathic; precise mechanism is unknown and likely involves myopathic, neurologic, and metabolic causes	Calf cramping at night
		Numerous etiologies
Gout	Peripheral monoarthritis caused by deposition of sodium urate crystals in the joints	Pain and redness typically in the big toe (metatarsophalangeal joint)
		Hyperuricemia

PAD peripheral arterial disease, ABI ankle-brachial index

How Many Pulses Should Be Examined?

Seventeen pulses should be examined: superficial temporal, carotid, brachial, radial, femoral, popliteal, posterior tibial, dorsalis pedis bilaterally, and aortic.

In Addition to a Pulse Deficit, What Other Findings on Leg Examination Would Support PAD?

PAD causes a progressive loss of blood supply to the leg. The calf muscles atrophy; hair appendages die (hair loss), as do sweat glands (dry scaly skin); the skin thins out (shiny); and ulcers may develop. Capillary refill time becomes prolonged (normal is ≤ 2 seconds). These features and bilateral involvement will help differentiate chronic lower extremity disease (PAD) from acute embolus leading to acute limb ischemia.

Watch Out

Ulcers at the most distal aspects of the extremities (e.g., toes) are generally arterial in etiology, whereas more proximal ulcers (e.g., malleoli) are generally venous in etiology.

Anatomy

What Muscle Groups Are Affected By Claudication?

Claudication may affect all the major muscle groups associated with walking, including the buttock, anterior thigh, calf, and rarely the foot muscles. The calf muscles are supplied by the superficial femoral artery (SFA). The SFA, which travels through the Hunter/adductor canal, is the most common site for atherosclerosis in the lower extremities; therefore, calf claudication is the most common location of pain. The internal iliac arteries supply the buttocks. Thus, stenosis above the internal iliac arteries (aorta, common iliac arteries) would cause buttock claudication. The hamstrings are not primarily utilized with walking. Thus, pain in the back of the thigh is not characteristic of claudication. Foot claudication is extremely rare and is most often due to isolated tibial artery disease.

Where Is the Hunter/Adductor Canal Located?

This aponeurotic tunnel extends from the apex of the femoral triangle to the opening of adductor magnus (adductor hiatus). The SFA runs through this canal and becomes the above-knee popliteal artery just distal to it. The femoral triangle is bounded superiorly by the inguinal ligament, medially by the adductor longus, and laterally by the sartorius muscle.

Watch Out

The common femoral artery is the most common location of arterial emboli, while the more distal SFA is the most common location of atherosclerotic plaque.

Pathophysiology

What Is Dependent Rubor?

Dependent rubor is a sign of advanced chronic ischemia. It occurs when dermal arterioles and capillaries no longer constrict in the presence of increased hydrostatic pressure. The arterioles in the foot become vasodilated in an effort to maximize blood and oxygen delivery. The vasodilation results in pooling of blood in the foot when it is in a dependent position. Patients with dependent rubor already have ischemic rest pain or are much more likely to progress to ischemic rest pain or nonhealing ulcers than patients with claudication alone.

Why Is the Onset of Pain Consistently at the Same Walking Distance?

Claudication is usually caused by an atherosclerotic plaque, which is a fixed lesion that reduces the blood flow consistently by the same amount, provided the effort level is the same. As such, patients can often pinpoint the exact distance they can walk before the onset of pain. This helps distinguish the symptoms from other causes of leg pain. If the patient reports a very wide range in walking ability (for instance, 1 day can only walk a few steps, another day can walk a mile), such symptoms would be inconsistent with claudication. Slight variability in the onset of pain, on the other hand, would support a diagnosis of claudication, provided the variability occurs when effort level changes, such as when walking faster or slower or up or down a hill, as oxygen demand will be different depending on the degree of effort.

What Other Disease Processes Can Cause Claudication?

Buerger's disease, chronic embolization (though embolization is more likely to cause acute limb ischemia), vasculitis, and entrapment of the popliteal artery can also cause claudication.

What Condition Is Classically Associated with Claudication in the Upper Extremities?

Subclavian steal syndrome is classically associated with claudication of the upper extremities. An atherosclerotic plaque contributes to the narrowing of the subclavian artery, causing retrograde flow in the vertebral artery during arm exercise. Patients report transient vertigo, dizziness, and less commonly syncope, during arm exercise.

What Is Buerger's Disease?

It is also known as thromboangiitis obliterans and seen in young (<40 years), predominantly male, smokers. It is an inflammatory and thrombotic process that causes occlusion of small- to medium-sized arteries, veins, and nerves of the upper and lower extremities. Patients present with claudication of the leg, foot, arm, or hand, which can progress to ischemic rest pain and ulcerations of the toes, feet, and fingers. It is associated with a high rate of amputation and a lack of response to angioplasty or bypass. The only effective treatment is smoking cessation.

What Is Leriche's Syndrome (Aortoiliac Occlusive Disease)?

It is a chronic, slowly developing occlusion of the infrarenal aorta most often seen in smokers, characterized by a triad: (1) bilateral hip, buttock, and thigh claudication, (2) absent femoral pulses, and (3) impotence. Since the aorta is occluded, the blood flow to the internal iliacs is compromised, which in turn decreases blood supply to internal pudendal arteries causing erectile dysfunction. Because of the slow progressive nature, collaterals have time to enlarge and compensate, such that most patients only have claudication and not ischemic rest pain.

Workup

What Is the Next Step in the Diagnostic Workup?

The ABI and arterial duplex scan are the next steps in the diagnostic workup. The ABI measures the systolic pressure in the foot (ankle) and compares it to the arm (brachial artery). The normal ABI ranges from 1 to 1.2 because the ankle pressure in the supine position can be as much as 20% higher than in the arm.

How Is the ABI Measured?

It is measured with the patient in a supine position. A handheld Doppler and a blood pressure (BP) cuff are needed to measure ABI. The BP cuff is inflated, while the Doppler is held on the dorsalis pedis artery. The cuff is inflated until the Doppler signal disappears. The cuff is slowly deflated until the signal returns. The systolic pressure at which the signal returns is recorded. The process is repeated with the posterior tibial and bilateral brachial arteries. The ABI is the ratio of the highest systolic pressure at the ankle or foot (of the side in question) over the highest brachial systolic pressure (of right or left side). The arterial duplex scan uses a combination of ultrasound to detect plaques in the arteries and Doppler to detect areas of elevated velocity of blood flow, indicating that the plaque is causing a hemodynamically significant stenosis.

Watch Out

The API (arterial pressure index) is used in trauma and compares the systolic pressure in the injured extremity with the contralateral uninjured extremity. A value < 0.9 is considered abnormal.

How Is PAD Defined?

■ Table 57.4

Normal ABI	1.2–1.0
Mild disease	0.9–0.7
Moderate disease	0.7–0.4
Severe disease/rest pain	<0.4

Watch Out

PAD is defined as ABI < 0.9.

What Is the Typical ABI of a Patient with Claudication? Rest Pain?

Patients with claudication usually have an ABI in the 0.6–0.8 range. Patients with ischemic rest pain usually have an ABI < 0.4.

What Additional Studies Are Recommended?

Further diagnostic studies would include either computed tomography angiography (CTA) or magnetic resonance angiography (MRA). However, these are only recommended for patients in whom an intervention is being planned (■ Figs. 57.1 and 57.2).

Is There Any Value in Screening an At-Risk Population for Asymptomatic PAD?

Patients with asymptomatic PAD have the same risk of adverse cardiovascular events (stroke and myocardial infarction) as patients with symptomatic PAD. As such it is of benefit to detect asymptomatic PAD to modify risk factors.

Prognosis

What Is the Risk of Limb Loss for Patients with Claudication?

Provided the patient does not have ischemic rest pain or tissue loss, the 5-year risk of limb loss for all comers with claudication is surprisingly low at 5%. The 10-year risk of limb loss is 10%.



Fig. 57.1 Coronal CT angiogram showing a normal aorta and common iliac arteries



Fig. 57.2 Coronal CT angiogram showing occlusion of the abdominal aorta just below the renal arteries

What Is the Risk of Limb Loss for Patients with Ischemic Rest Pain in the Foot?

Rest pain makes it highly likely (50%) that the patient will have limb loss at 1 year without intervention.

What Symptoms/Signs Are Considered Limb-Threatening PAD and Thus an Indication for More Aggressive Management?

Ischemic rest pain, nonhealing ulcer, and gangrene are among the symptoms/signs.

Management

What Is the Initial Management of Claudication?

Since the risk of limb loss is so low, medical management is considered the initial approach with the aim of lowering modifiable risk factors. This should include smoking cessation and exercise (specifically a walking program). Slowly walking 45 minutes a day for at least a month has been shown to be the best way to increase walking distance. In addition, control of hypertension, coronary artery disease hypercholesterolemia, diabetes, and obesity with antihypertensives, aspirin, statins, glucose control, and dietary changes are recommended. These latter modifications may help halt the progression of atherosclerosis, though these measures will not likely result in a direct observable improvement in walking distance.

Watch Out

Patients with claudication who continue to smoke are more likely to progress to rest pain and limb loss than non-smokers.

Are There Any Drugs Specifically Approved by the Food and Drug Administration (FDA) for Claudication?

Two drugs are FDA approved for claudication, but only one is considered effective. *Cilostazol* is a quinolinone derivative that has several actions but primarily inhibits platelet aggregation and smooth muscle proliferation, increases vasodilation, and lowers triglyceride level. Studies have shown that about 50% of patients note improvement in claudication after about a month of usage. It is considered the drug of choice

but is contraindicated in patients with heart failure. *Pentoxifylline* is a methylxanthine derivative and is also FDA approved, though studies suggest that it is no better than placebo. It is a rheologic agent that lowers blood viscosity. It also increases red blood cell deformability to permit easier passage of red blood cells through the capillaries.

What About a Statin? Does It Improve Claudication?

A statin should be given to most patients with PAD, even if the cholesterol levels are normal, as it has been shown to stabilize plaques via its anti-inflammatory effect and reduces the risk of stroke and myocardial infarction. In those with elevated cholesterol levels, the target is to lower the low-density lipoprotein (LDL) to <100 mg/dL. If the patient has additional risk factors (such as prior myocardial infarction or diabetes), the target level is <70 mg/dL. Statins, though indicated, have not been shown to directly improve walking distance.

What About Aspirin? Does It Improve Claudication?

Aspirin is recommended. Since there is a strong association between PAD and coronary and carotid atherosclerosis, aspirin is given to help prevent stroke and myocardial infarction. Aspirin inhibits platelet aggregation. It does so by suppressing the platelet's ability to produce thromboxane A₂ due to its irreversible inactivation of the cyclooxygenase (COX) enzyme. Aspirin, though indicated, has not been shown to directly improve walking distance.

What About Clopidogrel?

Clopidogrel irreversibly inhibits platelet aggregation. It does not directly lead to an improvement in claudication or walking distance, though it is utilized in PAD, as it has been shown to reduce the composite end point of stroke, myocardial infarction, or other vascular deaths in patients with PAD. However, there is debatable benefit to its routine use in combination with aspirin.

What About Anticoagulants Such As Heparin or Warfarin?

Claudication is due to an atherosclerotic plaque obstructing the blood flow and *not* a blood clot or embolization. As such, there is no role for anticoagulants.

What Are the Invasive Therapeutic Options?

Invasive therapeutic options are endovascular angioplasty/stenting (preferable in most patients) and open surgical techniques (endarterectomy or bypass).

If Medical Management Fails, Which Patients with Claudication Are Candidates for an Invasive Therapeutic Approach?

Patients with disabling claudication (Rutherford class 2 or 3) are candidates for invasive treatment provided (1) they are good-risk candidates for an intervention and (2) the symptoms are significantly affecting their lifestyle. For example, an elderly frail patient on home oxygen for pulmonary disease would not be a good-risk candidate, and their walking distance is more likely limited by their pulmonary disease than by the PAD. A security guard or a mail carrier would much more likely be limited by the PAD (and benefit from intervention). There is no role for invasive intervention in asymptomatic PAD.

Which Patients with PAD Should Go Directly to an Invasive Therapeutic Approach Rather than an Initial Attempt at Medical Management?

Patients with Rutherford classes 4–6 should go directly to an invasive therapeutic approach as their risk of limb loss is significantly higher.

What Is the 5-Year Mortality for Patients with PAD?

Mortality for patients with PAD is 30% at 5 years and is *primarily due to myocardial infarction*, followed by stroke. Mortality is even higher for patients who continue to smoke.

Key Areas Where You Can Get in Trouble

Confusing the Dependent Rubor of Rest Pain with Cellulitis (or Confusing Dependent Rubor with a Well-Perfused Foot)

In patients with advanced PAD, ischemic rest pain is constant, requiring the patient to even sleep with their feet dangling or to sleep in a chair. This may lead to some dependent edema in the leg as well as to dependent rubor. The combination of redness and edema may confuse the diagnosis, and the clinician can mistake ischemia with cellulitis. The two

can be distinguished by raising the foot. In ischemia, the red skin will be cool to touch, and upon elevation for 1–2 minutes, the rubor will disappear, and the foot will turn pale. With cellulitis, the red skin will feel warm, and the red color will *persist* with elevation.

Assuming that an ABI of 1.0 Is a Sign of Normal Circulation in a Diabetic Patient

Diabetic patients may develop falsely elevated (>1.2) or falsely normal ABIs. Diabetic patients develop a unique form of arteriosclerosis known as *Monckeberg's arteriosclerosis* or *medial calcinosis*. It involves intense calcification of the medial layer of the artery (typically the tibial vessels below the knee), which causes them to become rigid like a lead pipe. The result is that when one attempts to obtain an ABI, the blood pressure cuff is either unable to compress the artery or the pressure required to compress the artery is falsely elevated. This typically affects the tibial vessels sparing digital vessels in the toes. As such, toe pressures in diabetics are more reliable, as are other measures of distal perfusion including transcutaneous oximetry.

Areas of Controversy

Should a Patient with Claudication Who Is Still Smoking Undergo an Invasive Procedure?

As explained above, claudication (in the absence of ischemic rest pain) is not considered limb threatening. The primary treatment modality is lifestyle and risk factor modification. Studies have shown that if a patient continues to smoke, the disease will progress. Smoking is associated with worse outcomes for angioplasty, stenting, and bypass. Thus, many surgeons do not advocate pursuing an aggressive intervention until the patient has quit smoking. The counterargument is that the patient may need to see an immediate improvement in walking in order to embrace a healthier lifestyle.

In a Patient with Advanced Chronic Limb Ischemia (Tissue Loss, Rutherford Class 5 or 6), Is It Better to Attempt Endovascular Approaches (Angioplasty/Stenting) or to Perform an Open Surgical Bypass (Using Reverse Saphenous Vein)?

Short-term outcomes (in terms of limb salvage) appear to be the same using endovascular and open surgical bypass approaches, though the endovascular approach is less invasive. However, some studies suggest that open surgical bypass provides better long-term (beyond 2 years) limb salvage rates.

Summary of Essentials

History

- Calf, thigh, or buttock pain with walking, relieved by rest, reproducible at same distance is suggestive of claudication.

Physical Exam

- Absent pulses, muscle atrophy, hair loss, dry and atrophic skin, toe ulcers, and thickened toenails suggest PAD.

Pathology/Pathophysiology

- SFA is the most common site of atherosclerotic disease in the lower extremities (Hunter's canal).

Differential Diagnosis

- Neurogenic claudication (spinal stenosis), arthritis, sciatica, and chronic venous stasis.

Diagnosis

- By history and physical exam supplemented by ABI with Doppler
- Reserve CT or MR angiogram only if intervention is planned

Management

- Conservative for claudication (Rutherford classes 1–3): smoking cessation, walking program, statin, and aspirin.
- Best drug for PAD is cilostazol (improves walking distance).
- Interventional if with ischemic rest pain or tissue loss (Rutherford classes 4–6).
- Invasive treatment options include angioplasty/stenting (for stenosis and short occlusions), endarterectomy, and surgical bypass (long occlusions).

Prognosis

- Five-year risk of limb loss only 5% with claudication
- Five-year mortality 30% (due mainly to MI)

Special Situations

- Subclavian steal syndrome: arm claudication and dizziness
- Leriche's syndrome: buttock claudication, absent femoral pulses, and impotence
- Buerger's disease: young male smokers with distal artery and vein occlusions

Watch Out

- Falsely normal ABI in diabetics with medial calcinosis

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Sudden Onset of Severe Left-Sided Abdominal Pain

Michael de Virgilio and Nina M. Bowens

Case Study

A 67-year-old obese male presents to the emergency department with sudden onset of severe left-sided abdominal pain that radiates to the left flank and back. The pain began 2 hours ago while he was watching television. He has never had the pain before. He denies any nausea or vomiting, changes in bowel habits, or bloody/black stools. Past history is significant for chronic obstructive pulmonary disease (COPD) and well-controlled hypertension. He does not drink alcohol but has a 35 pack-year smoking history. On physical exam, blood

pressure is 90/60 mmHg, heart rate is 120/min, respiratory rate is 24/min, and he is afebrile. He appears to be in moderate distress secondary to pain and is diaphoretic. Lungs are clear bilaterally to auscultation without rales or rhonchi. Cardiac exam reveals a regular rhythm without murmurs, rubs, or gallops. His abdomen is moderately tender to palpation diffusely but worse in the mid-abdomen and in the left lower quadrant. He has no rebound or guarding. A palpable tender pulsatile mass is felt in

the midline just above the umbilicus. Rectal exam reveals no blood, stool, or masses. Femoral, popliteal, and pedal pulses are 1+ bilaterally. Laboratory examination reveals a hemoglobin of 10.1 g/dL (normal 12.3–15.7 g/dL), hematocrit of 30.3% (37–46%), and white blood cell count of $11 \times 10^3/\mu\text{L}$ ($4.1\text{--}10.9 \times 10^3/\mu\text{L}$), aspartate aminotransferase (AST) of 44 μL (5–35 μL), alanine aminotransferase (ALT) of 65 μL (7–56 μL), lipase of 50 u/L (7–60 u/L), and amylase of 62 u/L (30–110 u/L).

Diagnosis

What Is the Differential Diagnosis?

Table 58.1

Diagnosis	History and physical examination
Ruptured AAA	Caucasian, elderly, male, smoker with sudden onset of severe abdominal, left flank, left groin, and/or lower back pain; pulsatile abdominal mass; tachycardia; and hypotension
Perforated gastric or duodenal ulcer	Sudden onset of epigastric pain which then becomes diffuse, history of steroid or chronic NSAID use, abdominal guarding, rigidity, and rebound tenderness
Aortic dissection	Sharp, tearing chest pain radiating to the back; history of hypertension
Pancreatitis	Epigastric pain radiating to the back, nausea, vomiting, anorexia, fever and tachycardia associated with cholelithiasis, alcohol abuse
Diverticulitis	Pain begins in left lower quadrant and may become diffuse; fever, nausea, diarrhea, constipation, common in elderly

AAA abdominal aortic aneurysm, NSAID nonsteroidal anti-inflammatory drug

What Is the Most Likely Diagnosis?

In a patient with significant risk factors (e.g., age ≥ 65 , smoking, hypertension, COPD) presenting with a palpable pulsatile abdominal mass, acute onset of abdominal pain that is radiating to the left flank, and signs consistent with shock (e.g., hypotension, tachycardia, pallor, and diaphoresis), along with anemia without other sources of obvious blood loss, the most likely diagnosis is a ruptured abdominal aortic aneurysm (AAA).

History and Physical Examination

What Is the Typical Presentation for an Unruptured AAA?

Most unruptured AAAs are asymptomatic and therefore go undetected. The first symptom of AAA in most patients is rupture, which is often fatal. For this reason, AAA is referred to as a silent killer. Most AAAs are discovered incidentally (CT, ultrasound) in the course of a workup for other medical problems. Rarely, as an AAA enlarges, patients can experience chronic lower back pain from compression of the spine. Thrombus commonly forms within the outer walls of an AAA. Though uncommon, the thrombus can embolize distally to the lower extremities resulting in acute limb ischemia.

What Are the Risk Factors for AAA?

Risk factors include smoking, age ≥ 65 , Caucasian race, male, coronary artery disease, a history of extra-abdominal aneurysm such as femoral or popliteal aneurysms, peripheral arterial disease, family history of AAA, and hypertension. COPD is also a risk factor for AAA and is independent of smoking.

Watch Out

Smoking is by far the *strongest* risk factor for AAA, while hypertension is the strongest risk factor for aortic dissection. Smoking one or more packs of cigarettes a day is associated with a 12-fold increased risk for developing an AAA.

Is Diabetes a Risk Factor for AAA?

No. While diabetes is an important risk factor for intimal atheroma formation, myocardial infarction, stroke, and peripheral arterial disease, it is actually *protective* against AAA. While the protective mechanism of diabetes is not fully

understood, one hypothesis is that glycation of matrix metalloproteinases (discussed in *Pathophysiology*) leads to their deactivation and thus decreases aortic remodeling.

Is There a Role for Physical Examination in the Detection of AAA? What Are the Limitations?

Physical examination for the detection of AAA can be useful when carefully performed. The sensitivity/specificity of the physical examination for AAA increases as the AAA size increases and decreases as the patient's body mass index increases. Obesity is the biggest limiting factor in diagnosing an AAA on physical exam. In addition, the value of physical examination varies by practitioner and is limited in detecting smaller aneurysms.

Is There a Role for AAA Screening? If So, Who Should Be Screened and How Often?

The American College of Cardiology, American Heart Association, and the US Preventive Services Task Force recommend screening with physical exam and one-time abdominal ultrasound for men between ages 65 and 75 who have had *any* smoking history. First-degree relatives of a patient with AAA should be screened at age 65. If an AAA is found, it should be followed by annual ultrasonography if it is between 4.0 and 4.9 cm and biannually if between 5.0 and 5.4 cm.

Watch Out

Screening for AAA with a one-time ultrasound is recommended for *male* smokers between ages 65 and 75. There is insufficient evidence to recommend screening in women who smoke.

In a Patient with an AAA, What Other Arteries Might Have Aneurysms? How Would You Screen for Them? What Is the Main Risk Associated with Those Aneurysms?

Femoral and popliteal artery aneurysms are associated with AAA, with popliteal artery aneurysms being more common. The main risk associated with these peripheral aneurysms is limb ischemia from thrombosis (more common) and/or distal embolization. These peripheral aneurysms can compress adjacent structures such as nerves or veins. Femoral and popliteal aneurysms can sometimes be detected on physical exam and are bilateral in 50% of patients. However, duplex ultrasonography is the recommended screening modality in patients found to have AAA. Femoral aneurysms can present with thigh pain while walking, while popliteal aneurysms can present with calf pain while walking.

Watch Out

Thoracic aneurysms can present with dysphagia, hoarseness, dyspnea, and upper extremity edema due to mass effect and compression of the central veins.

Watch Out

The most common *visceral* artery aneurysm is splenic.

Pathophysiology

What Is the Normal Diameter of the Infrarenal Aorta in Men? Women?

The normal size of the infrarenal aorta is 2.0 cm in men and 1.8 cm in women.

What Is the Primary Defect in AAA?

Although AAA is a multifactorial disease process, it ultimately results from the degeneration of the medial layer through degradation of elastin and collagen.

At What Diameter Is the Infrarenal Aorta Considered to Be Aneurysmal?

For an artery to be considered an aneurysm, there must be a focal area that is 1.5 times larger than the diameter of the non-aneurysmal artery above. In the case of the infrarenal aorta, this would mean a diameter of about 3 cm or more.

What Is the Average Annual Growth Rate of AAA?

Studies examining the annual growth rate of small AAAs estimate a rate of 2–4 mm/year. Patients found to have rapid expansion (>5 mm/6 months) should be referred for elective repair. In addition, routine monitoring is important as expansion tends to be in stepwise growth spurts rather than linear.

What Factors Influence Growth Rate?

Ongoing smoking has been found to increase growth rate of AAA, whereas patients with diabetes have slower growth rates. The use of blood pressure medications has not been shown to consistently slow the growth rates of AAA.

What Are Matrix Metalloproteinases (MMPs), and What Is Their Role in AAA Formation?

MMPs are important for collagen turnover, which is vital to inflammation and wound healing. Patients with AAA have abnormally high levels of MMP activity in the aortic wall, which weakens the arterial wall and contributes to the dilation of the aneurysm over time.

Watch Out

Statin drugs have been shown to reduce the activity of MMPs and may therefore be beneficial in AAA.

Is There a Genetic Component to AAA Formation?

Family history is a risk factor for AAA. First-degree relatives of patients with AAA have up to a 12-fold higher risk of developing the disease, and the risk is even higher in siblings of patients with AAA. Interestingly, whereas male gender is an independent risk factor for AAA, familial groupings of AAA tend to occur more often in female relatives.

If an AAA Ruptures, Where Does It Typically Do So?

AAAs most commonly rupture into the retroperitoneum (the aorta is a retroperitoneal structure) and most often to the left (the vena cava is on the right and may prevent rupture to that side). Free rupture into the peritoneum is rare and would likely lead to immediate death as there is no ability to tamponade the bleeding.

Watch Out

Rarely, an AAA can erode into the inferior vena cava or iliac veins, creating an aortocaval fistula. These patients classically present with high output congestive heart failure, bilateral leg edema, and an abdominal bruit or thrill. Rarely, patients may have hematuria with retroperitoneal congestion.

What Is the Relationship Between AAA Rupture and Size?

As the aneurysm enlarges, the risk of rupture also increases. AAA with a 4–5 cm diameter has a < 1% annual chance of rupturing versus 30–50% in an AAA >8 cm diameter.

Other Than AAA Size, What Are Other Risk Factors for AAA Rupture?

Poorly controlled blood pressure, COPD (*increase in systemic proteinase activity*), and female gender (smaller aortas to begin with) have been associated with an increased risk of AAA rupture.

What Are the Primary Differences Between an Aortic Dissection and an AAA?

Table 58.2

	Aortic dissection	AAA
Population	White male \geq age 65 or young patients with connective tissue disease (e.g., Marfan, Ehlers-Danlos)	White male \geq age 65
Strongest risk factor	Hypertension	Smoking
Presentation	Sharp, tearing chest pain radiating to the upper back	Usually asymptomatic; if ruptured, will present with severe abdominal pain, pulsatile abdominal mass, and shock
Pathophysiology	Intimal tear with dissection of blood through the medial layer forming a true and false lumen	Multifactorial processes leading to weakened medial layer
Location	Ascending aorta/aortic arch (Stanford A) or descending thoracic aorta (Stanford B) (distal to left subclavian); high stress regions	Usually arises below renal arteries but above the iliac arteries

Workup

What Is the First Step in the Evaluation of a Patient with a Suspected Ruptured AAA?

One should always start with the ABCs of management of unstable patients with two important caveats regarding intubation and fluid management (see below). If the patient

is not in respiratory failure, intubation should be *delayed* until the patient is in the OR and prepped and draped before anesthetic induction. The drugs used to intubate tend to make the patient more hypotensive and so the surgeon must be prepared to immediately make a skin incision. Two large-bore IVs should be established, one in each antecubital fossa.

In a Patient with Suspected Ruptured AAA, What Is the Goal of Fluid Resuscitation?

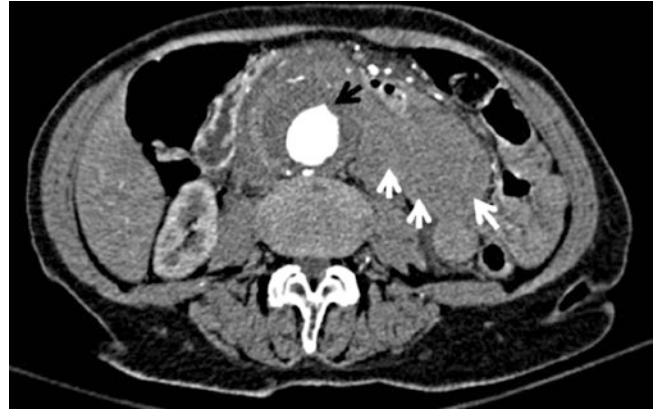
Intuitively, one would want to aggressively volume resuscitate the patient with large fluid boluses. However, in the setting of a suspected ruptured AAA, initial fluid resuscitation should be *limited*. Studies in penetrating trauma with vascular injury as well as in patients with ruptured AAA have advocated permissive hypotension rather than resuscitation, so as to maintain normal mentation (not with the goal of restoring a normal systolic blood pressure). Keep in mind that the hole in the aorta from rupture is temporarily contained by vasoconstriction and clot formation. Massive fluid resuscitation prior to surgery tends to exacerbate hemorrhage by diluting out coagulation factors and by raising systolic blood pressure.

What Imaging Is Recommended for Suspected Ruptured AAA in a Hemodynamically Stable Patient?

In a stable patient, the recommended imaging modality for suspected ruptured AAA is a computed tomography angiography (CTA). This offers the benefits of (1) confirming whether there is a ruptured AAA versus another diagnosis and (2), if it is a ruptured AAA, determining whether an endovascular approach is feasible (■ Figs. 58.1 and 58.2).



■ Fig. 58.1 Axial CT showing a normal aorta



■ Fig. 58.2 Axial CT showing a ruptured abdominal aortic aneurysm with thrombus and large left-sided fluid collection consistent with rupture. Black arrow: thrombus. White arrows: fluid collection

How Does the Imaging of Choice Differ in a Hemodynamically Unstable Patient?

In the hemodynamically unstable patient, there is no role for CT scan. If the patient presents with severe abdominal pain and tenderness on exam, combined with a pulsatile mass and hemodynamic instability, the patient should be taken directly to the operating room for an exploratory laparotomy. If there is no obvious pulsatile mass and time permits, a bedside abdominal ultrasonography is used to confirm the presence of a large AAA. Since the rupture is usually retroperitoneal, the ultrasound will not demonstrate the rupture nor will it show intraperitoneal fluid. As such, a presumptive diagnosis of a ruptured AAA is made by combining the clinical presentation, physical exam, and the finding of a large AAA on ultrasound.

Management

How Does AAA Size and Growth Rate Influence Management for an Asymptomatic AAA?

■ Table 58.3

AAA measurement	Management
3.0–3.9 cm	Ultrasound every 3 years
4.0–4.9 cm	Annual ultrasound
5.0–5.4 cm	Ultrasound every 6 months
>5.5 cm	Elective repair
Enlarging >1 cm/year or symptomatic	Elective repair

Non-ruptured Asymptomatic AAA

Why Wait for the AAA to Reach this Size, Why Not Repair a Smaller AAA Since the Patient Is Theoretically Healthier and Is Younger?

The annual risk of rupture for an aneurysm <5.5 cm is very low, and morbidity and mortality of repair are greater than the risk of death from rupture. Two large studies have demonstrated no survival benefit for early intervention for AAA <5.5 cm. Since the diameter of aorta is smaller in women and women with AAA have a higher risk of rupture, the threshold for repair may be lower (4.5–5 cm).

What Surgical Options Are Available for Asymptomatic AAA?

The two available options are open repair and endovascular aneurysm repair (EVAR) with EVAR being the preferred approach.

Watch Out

The main source of perioperative morbidity and mortality following both open repair and endovascular AAA repair is myocardial infarction.

How Do the Two Surgical Approaches Compare in Terms of Perioperative Morbidity and Mortality? What About Long-Term Mortality?

EVAR has a lower perioperative mortality rate compared to open repair. However, long-term survival is *equivalent* for open repair and EVAR. This is likely related to the fact that EVAR reduces but does not eliminate the risk of AAA, and EVAR is associated with higher rates of re-intervention and re-intervention-associated complications. EVAR also has higher costs.

Ruptured AAA

What Are the Surgical Options for a Patient with a Ruptured AAA?

Patients with suspected rupture of an AAA can also undergo open repair or EVAR. If the patient is hemodynamically unstable, open repair is more expeditious. If the patient is relatively stable, either approach is appropriate (assuming that the patient is an EVAR candidate based on CT scan). Recent studies show that outcomes are the same for both approaches in terms of mortality. Alternatively, a resuscitative endovascular balloon occlusion of the aorta (REBOA) can be placed as soon as the patient arrives to the hospital to temporarily control bleeding while the patient is transported to the operating room.

What Makes an AAA Unsuitable for EVAR?

The primary factor is whether there is space to deploy the stent between the takeoff of the renal arteries and the start of the infrarenal aneurysm (known as the aortic neck). If the neck is too short, standard EVAR techniques are not possible.

What Is the Mortality Risk if an AAA Ruptures?

Overall mortality from AAA rupture is estimated at 80–90%. Approximately half of all patients with ruptured AAA die before reaching a hospital, and of those who do arrive to the hospital alive, about 50% will die.

What Is the Main Achilles Heel of Endovascular Repair?

The main concern of EVAR is failure to fully exclude the aortic aneurysm. Persistent arterial flow into the aneurysm sac is known as an endoleak (■ Table 58.4). The concern of a persistent endoleak, particularly one at a high systolic pressure, is that the aneurysm will continue to grow and may eventually rupture despite treatment with EVAR. At the end of EVAR, a completion angiogram is performed which will help identify an endoleak before leaving the operating room. After successful EVAR, patients require at least an annual lifetime follow-up to determine if an endoleak develops later.

How Should Patients Be Monitored After an Endovascular AAA Repair?

Following EVAR, the gold standard for monitoring is CTA. Patients undergo CTA at 1 month and 1 year following EVAR and then yearly to evaluate for late endoleak. Duplex ultrasonography is an adjunctive tool for EVAR surveillance, although it has diminished specificity when compared to CTA.

■ Table 58.4 Five types of endoleaks

Type	Features
I	Anterograde or retrograde flow from inadequate proximal or distal seal of the stent graft against the arterial wall; most worrisome and <i>requires repair</i> before leaving the operating room
II	Retrograde flow from patent branches within the aneurysm sac (i.e., lumbar, inferior mesenteric); <i>most common</i> , usually benign, and does not lead to sac growth
III	Flow between junctional areas of overlapping stents within the aortic and iliac vessels
IV	Flow through the graft due to overly porous stent material or fabric tear
V	Also referred to as <i>endotension</i> ; considered idiopathic as sac enlarges without evidence of a leak site

Areas Where You Can Get in Trouble

Assuming that an AAA Is Not Ruptured Because No Contrast Extravasation Is Seen on CT

If a patient with a ruptured AAA did not die in the field and has arrived at the hospital with reasonable vital signs, it usually implies that the site of rupture has temporarily contained itself and that there is no ongoing exsanguination. Thus, CT scan imaging of a ruptured AAA will typically demonstrate fluid or stranding in the retroperitoneum (representing clotted blood) adjacent to the AAA, but no actual contrast extravasation. In the setting of a patient presenting with acute abdominal pain, the finding of adjacent retroperitoneal fluid next to an AAA represents a ruptured AAA until proven otherwise.

Ignoring Early-Onset Diarrhea After AAA Repair

A major concern following abdominal aneurysm repair, via both the open and endovascular approaches, is postoperative ischemic colitis, typically as a consequence of ligating/excluding the inferior mesenteric artery (IMA). Patients will develop abdominal pain, leukocytosis, and bloody diarrhea (though not always bloody) in the first few postoperative days. Workup consists of performing a *flexible sigmoidoscopy* as the descending (watershed area of splenic flexure) or sigmoid colon are usually affected. There is usually no need for a complete colonoscopy or angiography. The goals of treatment are primarily supportive, including fluid hydration, keeping the patient NPO, and administering broad-spectrum IV antibiotics to cover gram-negative aerobes and anaerobic organisms. Surgical intervention (sigmoid colon resection with colostomy) is reserved for patients who clinically deteriorate or have peritonitis, or those with full-thickness necrosis.

Watch Out

The *greatest* risk factor for ischemic colitis following AAA repair is hypotension and hypoperfusion in the setting of a ruptured AAA.

Not Considering Aortoenteric Fistula as a Cause of GI Bleed After AAA Repair

An aortoenteric fistula is an erosion between the aorta and the duodenum, most commonly seen after AAA repair. It can present months or years after AAA repair with upper GI bleeding or melena. The fourth portion of the duodenum typically rests next to the aorta, near the proximal suture line where the continuous aortic pulsation results in erosion and fistula formation. Upper endoscopy is usually negative. Often the only

clue is air or fluid around the aortic graft on CT scan. Since the aortic graft is infected, management requires excision of the aortic graft with extra-anatomic reconstruction (axillary to bifemoral artery bypass), homograft, rifampin-soaked graft, or NAIS (NeoAortoiliac System) procedure and long-term antibiotics.

Ipsilateral Flank or Back Pain Following EVAR

Performing EVAR typically requires femoral artery catheterization. This can be complicated by a femoral artery pseudoaneurysm (pain, pulsatile mass, may compress adjacent structures), bleeding from the catheterization site, and, rarely, a retroperitoneal hematoma. Retroperitoneal hematoma may present with sudden hypotension (if brisk bleeding continues), tachycardia, suprainguinal tenderness, and ipsilateral flank or back pain. This is more common in women and patients with thrombocytopenia or on anticoagulation. This can be confirmed with CT imaging and typically resolves with blood products and reversal of coagulopathy.

Area of Controversy

Since EVAR Has a Lower Risk of Perioperative Mortality than Open Repair, Should We Lower Our Threshold for AAA Repair (i.e., < 5.5 cm) if the Patient Is an EVAR Candidate?

Although EVAR has a lower risk of perioperative complications and death than open repair, it is still associated with significant potential complications. In addition, patients with small AAA often have significant coexisting medical problems, so they are more likely to die in the long term from a cardiac event or from cancer than from a ruptured aneurysm. To date, there is no evidence that patients who are EVAR candidates would benefit from AAA repair at less than 5.5 cm.

Summary of Essentials

History and Physical Examination

- AAA is a silent killer; most are asymptomatic until rupture.
- Ruptured AAA should be suspected in elderly male smokers who present with acute abdominal pain radiating to the back or flank, hypotension, tachycardia, pallor, and diaphoresis.
- Many patients are obese, so a pulsatile abdominal mass may not be palpable.

Diagnosis

- In unstable patients, there is no time for a diagnostic workup, so diagnosis is based on history and physical exam.
- In stable patients, CTA will elucidate the anatomy and determine whether the patient is a candidate for endovascular repair.
- Abdominal ultrasound can diagnose the presence of an AAA and its size but is not accurate for determining rupture.

Screening

- Ultrasound screening
 - Men (not women) aged 65–75 with any smoking history or beginning at age 65 if they have a first-degree relative with AAA.
 - Patients with femoral or popliteal artery aneurysm.
 - An aortic diameter >3 cm is considered aneurysmal.

Management

- Ruptured AAA.
 - Obtain IV access but limit fluids.
 - Permissive hypotension (as low as 70 mmHg), maintain mentation.
 - Avoid intubation until in the operating room.
- Repair via open or EVAR.
- Consider placing endovascular balloon to occlude suprarenal aorta (REBOA).

- Non-ruptured AAA.
 - <5.5 cm, observe
 - >5.5 cm
 - Open or EVAR.

Complications

- Myocardial infarction is the most common cause of death.
- Colonic ischemia: postoperative bloody diarrhea (early, days after surgery).
- Aortoenteric fistula: GI bleed (late, months to years later).

Suggested Reading

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Cold, Painful Right Lower Extremity

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Case Study

A 65-year-old female presents to the emergency department with a 4-hour history of sudden onset of right leg pain, coolness, weakness, and numbness. She has no prior similar history. The pain began while she was sitting watching television. She has a history of hypertension and hypercholesterolemia and takes medication for both. She denies smoking. On review of systems, she has no prior history of pain in her right leg with walking. On physical

examination, her lungs are clear to auscultation. Her heart rate is irregularly irregular without murmurs, rubs, or gallops. Her abdomen is soft and non-tender without a pulsatile mass. On the left side, the femoral, popliteal, dorsalis pedis, and posterior tibial pulses are 2+, with biphasic signals on Doppler. On the right side, the femoral, popliteal, dorsalis pedis, and posterior tibial pulses are absent, with faint monophasic signals on Doppler. Her

right calf is tender to palpation but is not edematous. She has normal appearing, supple skin in her legs with a normal hair pattern. The left foot is pink and warm with a 2-second capillary refill and normal motor and sensory function. Her right foot is pale and feels much colder than the left; capillary refill time is 6 seconds. The toes have decreased sensation to touch. Her strength is diminished in both plantar flexion and dorsiflexion of the ankle at 4+/5.

Diagnosis

What Is the Differential Diagnosis?

Table 59.1

Differential diagnosis	Key features/findings
Acute limb ischemia	Pain, pallor, pulselessness, paresthesias, paralysis, and poikilothermia; history of PAD, atrial fibrillation
Compartment syndrome	Severe pain in calf with passive motion of ankle, tense leg edema, recent trauma, pulse present
Phlegmasia cerulea dolens	Cyanotic leg and edema, massive deep vein thrombosis, associated with malignancy; evaluate for recent prolonged stasis, hypercoagulable state, endothelial injury (<i>Virchow's triad</i>)
Cerebrovascular accident	May cause numbness and weakness but not pain or pulselessness; other neurological signs may be present
Disk herniation	History of back pain, DJD; paresthesias in dermatomal distribution (e.g., sciatica), possible weakness and sensory changes, but pulses present
Spinal cord tumor	Presents similarly to disk herniation; consider in patients with history of metastatic malignancy, normal pulses

PAD peripheral arterial disease, DJD degenerative joint disease

What Is the Most Likely Diagnosis?

This patient's presentation is most consistent with acute limb ischemia (ALI). The presence of motor weakness often creates confusion and may inappropriately steer the clinician toward a neurologic differential diagnosis. However, the pale, cold foot, combined with the absence of palpable pulses, as supported by monophasic Doppler signal, rules out the majority of the diagnoses in the differential. The presence of an irregularly irregular heartbeat (e.g., atrial fibrillation) points toward a cardioembolic etiology of the ALI.

History and Physical

What Is the Difference in Timing Between Acute and Chronic Limb Ischemia?

Acute limb ischemia (ALI) is defined as any sudden decrease in perfusion to a limb that endangers its viability. Limb ischemia is considered acute when the symptoms have been present for less than 2 weeks, whereas if greater than 2 weeks, it is considered chronic limb ischemia (CLI).

What Are the Six "Ps" of Acute Limb Ischemia?

Patients with ALI present with a constellation of signs and symptoms summarized by the "six Ps": **p**ain, **p**allor, **p**ulselessness, **p**aresthesias, **p**aralysis, and **p**oikilothermia/**p**erishing cold. Pulselessness is considered the defining feature of ALI, but pain is often the presenting symptom. Pain associated with ALI is frequently located in the foot and calf and occurs at rest. Numbness is present in more than half of the patients with ALI. Paralysis is the most ominous sign of the "six Ps" and is a sign of severe ischemia that may be irreversible.

Why Is the Cardiac History and Physical Important in Determining the Etiology of ALI?

An embolus is a common etiology (Table 59.2) for ALI with 80% of emboli coming from the heart. Atrial fibrillation, recent myocardial infarction, valvular disease, and congestive heart failure are all common conditions that predispose to cardioemboli. A focused cardiac history and physical examination should identify the presence of any of these diseases.

Watch Out

Abrupt cessation of warfarin (e.g., runs out of medication) in a patient with atrial fibrillation can lead to rebound hypercoagulability and higher risk of embolic events.

Table 59.2 Common causes of acute limb ischemia

	Etiology	Key features/findings
Thrombosis	Thrombosis of stenosed artery	Vascular risk factors, history of claudication, signs of chronic ischemia in contralateral limb
	Thrombosis of previous graft	Vascular risk factors, known previous graft, surgical scars
	Hypercoagulable disorder	Known coagulopathy, history of prior de novo arterial thrombosis, no prior history of atherosclerotic PAD
	Arterial trauma	Recent trauma, recent vascular intervention
Embolus	Cardioembolic	Atrial fibrillation, valvular disease, CHF, recent MI, ventricular aneurysm, left atrial myxoma
	Embolism from popliteal/aortic aneurysm	Palpable pulsatile abdominal mass or popliteal mass in contralateral leg (often bilateral)
	Paradoxical embolism	DVT sends clot to the heart, crosses cardiac septal defect with embolization to the arterial tree
Others	Acute aortic dissection	Type A (involves aortic arch), type B (descending aorta), tearing back pain, Marfan's syndrome, hypertension
	Systemic shock	Limb ischemia may be a late manifestation of severe shock, particularly with underlying chronic occlusive disease or high doses of vasopressors

PAD peripheral arterial disease, *CHF* congestive heart failure, *MI* myocardial infarction, *DVT* deep vein thrombosis

Watch Out

Atrial fibrillation is the most common cause of acute arterial emboli.

What Are the Key Findings that Point Toward an Embolic Etiology Rather than a Thrombotic Event?

An irregularly irregular rhythm (as in the patient above) or acute MI are highly suggestive of a cardioembolism. In addition, most thrombotic events occur in the setting of preexisting atherosclerosis in the leg arteries (which is usually a symmetric, bilateral process).

Why Is It Important to Examine the Contralateral, Nonischemic Limb?

Examining the contralateral leg allows the provider to compare each leg when assessing the subjective findings of pallor and poikilothermia. It also provides important clues regarding the etiology of ischemia. If the nonischemic limb has evidence of chronic decreased perfusion, such as diminished pulses, hair loss, or atrophic skin changes, this suggests that the patient has peripheral arterial disease (PAD), which raises suspicion for a thrombotic etiology of ALI. Since PAD is a diffuse disease process in the peripheral vasculature, the lack of any chronic ischemic changes in the contralateral leg makes an embolic cause more likely.

How Would You Best Assess This Patient's Atherosclerotic Disease History?

The patient should be asked about risk factors such as smoking, diabetes, hypertension, hypercholesterolemia, history of coronary artery disease and diabetes, and history of intermittent claudication.

Why Is It Important to Ask About Past Interventions for PAD?

It is important to determine if the patient has had previous interventions for PAD, as thrombosis of a previous graft is a frequent cause of ALI. Iatrogenic trauma such as that caused by recent arterial catheterization (e.g., for coronary stenting) may also cause arterial thrombosis.

Pathophysiology

Where in the Arterial Tree Do Cardiac Emboli Tend to Lodge?

Generally, emboli lodge at arterial bifurcations (Table 59.3) due to the sudden reduction in arterial diameter as the artery branches. The bifurcation of the common femoral artery is the most common location for an embolus to lodge in the lower extremity.

How Do Aneurysms Cause Acute Limb Ischemia?

An aneurysm is a focal area of arterial dilation. At its widest points, blood flow becomes static, with eddy currents (much like where a river suddenly widens), leading to clot formation. The clot can embolize distally.

Table 59.3 Common locations of lower extremity embolic occlusion and their presentations

Location	Pulses	Symptoms
Aortic bifurcation	Absent bilaterally	Bilateral pain/weakness of thighs/calves, mottling of skin distal to umbilicus
Common femoral bifurcation	Absent throughout affected limb	Unilateral calf and foot pain
Popliteal bifurcation	Femoral pulse present, pedal pulses absent; popliteal pulse may be present as well	Unilateral foot pain; calf pain may be present as well

How Does Peripheral Arterial Disease Lead to Acute Limb Ischemia?

Thrombotic causes of ALI (approximately 50–60% of cases) are usually associated with underlying atherosclerotic disease. There are two primary mechanisms believed to be responsible for atherosclerosis-related limb ischemia. Plaque buildup can lead to a progressive narrowing of the artery with subsequent low-flow states and stasis that can lead to sudden thrombosis of the artery. The second mechanism involves intraplaque rupture with local hypercoagulability and hemorrhage, which can also suddenly occlude the artery.

How Long Can Muscle Tissue Withstand Ischemia Before Irreversible Damage Occurs?

Physiologic studies show that after an acute ischemic event, skeletal muscle tissue begins to show signs of irreversible cell damage after 3 hours and progresses to complete cell damage at 6 hours. Thus, rapid diagnosis and treatment is essential in the suspected ALI.

Workup

What Does a Doppler Probe Detect and What Are the Three Signals?

Blood flow is detected by a handheld Doppler probe and converted to an audible acoustic signal. Doppler assessment is frequently more sensitive than the ability to palpate a pulse. The signal should be reported as triphasic, biphasic, monophasic, or absent. A healthy peripheral artery produces a triphasic signal (three sounds). This reflects initial forward systolic flow, followed by early-diastolic retrograde flow attributable to high resistance, and finally forward diastolic

flow. Biphasic signals are often normal but may represent an early disease state. Monophasic signals are clearly abnormal and signify a severe reduction in blood flow. Most patients with acute limb ischemia have absent Doppler signals or, at best, faintly monophasic signals. If a biphasic or triphasic arterial signal is present in the foot arteries, the diagnosis of acute limb ischemia should be questioned.

Is the Ankle-Brachial Index Useful for ALI?

The ankle-brachial index (ABI) is essential in the evaluation of chronic limb ischemia. With ALI, blood flow in the foot is severely reduced such that a blood pressure is typically not measurable; therefore, the ABI has limited utility.

How Is the Severity of Acute Ischemia Determined?

The severity of ALI is determined clinically, not radiographically. The presence of sensory and/or motor deficits are the most important prognostic factors. Doppler signal is also important as a measure of whether any arterial blood flow is present.

What Imaging Is Recommended?

The diagnosis of ALI is extremely time sensitive. Duplex ultrasound scanning is a simple and convenient imaging modality to use for initial evaluation of ALI. A normal duplex scan is an inexpensive way to effectively rule out ALI. Though it is useful for examining the affected limb, it does not provide information about the proximal arterial tree (aorta and iliac arteries). Thus, a computed tomography angiography (CTA) of the abdomen, pelvis, and both lower extremities is the gold standard as it can be performed quickly. Not only does it demonstrate the site of the occluded artery, it can often provide clues as to the etiology by demonstrating atherosclerotic plaques, aneurysms, or arterial dissection.

What Additional Imaging Should Be Done if an Embolus Is Suspected as the Cause for ALI? If a Paradoxical Embolus Is Suspected?

If an embolus is suspected, cardiac workup with *transthoracic echocardiography* should be performed. If there are particular historical clues to suggest a venous thrombosis with paradoxical embolus (such as recent flights, pelvic surgery, asymmetrically swollen limbs, etc.), venous duplex scanning of the lower extremities should be performed to evaluate for the presence of deep vein thrombus, and transthoracic echocardiogram and bubble study (intravenous injection of saline with bubbles

in it and monitoring for echocardiographic evidence of the bubbles in the left side of the heart) should be performed to assess for cardiac septal defects that may allow paradoxical embolism of venous clots into the arterial circulation.

Management

What Are the Three Most Important Initial Management Steps?

Anticoagulation with heparin should be started immediately (provided there is no contraindication such as bleeding) once the diagnosis of ALI is suspected. Do not wait for imaging in someone with a cold, pulseless foot. While heparin will not dissolve the clot, it is essential in *preventing* clot propagation into unaffected vascular beds, while the patient's own fibrinolytic system dissolves some of the clot. In addition to anticoagulation, the affected limb should be placed in a dependent position to improve flow. Finally, IV fluids should be started as volume expansion helps optimize perfusion through collateral vessels.

What Are the Main Therapeutic Options for Acute Limb Ischemia?

The two mainstay treatment options for ALI are endovascular and open surgical revascularization. Endovascular treatment relies on catheter-based methods to achieve clot dissolution; these include catheter-directed tissue plasminogen activator (tPA) thrombolysis, percutaneous aspiration thrombectomy, or percutaneous mechanical thrombectomy. Surgical options include surgical (Fogarty balloon) embolectomy, endarterectomy, and distal bypass. In some cases, heparin alone may be the best treatment option, particularly in patients with mild ischemia who at high risk for complications from thrombolysis or surgery. For example, in a patient who presents with an acute MI and is not stable for transport to the operating room or the endovascular suite, heparin alone may suffice if the ischemia is mild.

Watch Out

Unlike the trauma population where the contralateral vein is typically used, in patients with ALI undergoing bypass surgery, the *ipsilateral* greater saphenous vein is the conduit of choice.

What Are the Absolute Contraindications to Thrombolytic Therapy? Relative Contraindications?

Recent stroke or transient ischemic attack, active or recent bleeding, and significant coagulopathy. Relative contraindications

include recent (<2 weeks) major surgery, recent trauma, uncontrolled hypertension, intracranial pathology, and pregnancy. tPA should only be used for a maximum for 48 hours, at which point the risk of bleeding increases significantly.

How Does One Choose Between Open Surgery and Endovascular Therapy?

Endovascular therapy, though less invasive, may take 24–48 hours to be completely effective. Thus, it is appropriate and preferred for most patients with less severe ischemia (those with a normal motor/sensory exam) or with only a sensory deficit. Open surgical intervention is preferred for patients with severe ALI (those with a motor deficit) when immediate revascularization is indicated.

Who Is the Best Candidate for Surgical Balloon Embolectomy?

Surgical embolectomy (with a Fogarty balloon) is best used in the setting of cardioemboli lodged in the proximal femoral artery. If there is underlying atherosclerosis in the affected limb, an embolectomy will not work as it cannot remove underlying plaque.

What Is the Treatment for Irreversible Limb Ischemia?

When ALI presents with complete motor and sensory loss, the tissue damage is irreversible, so primary amputation should be performed. Attempting revascularization in this setting is contraindicated, as the risk of reperfusion injury is extremely high.

What Are the Potential Dangerous Sequelae of Reperfusion Following ALI?

Reperfusion of ischemic muscle can lead to a constellation of serious complications collectively known as *ischemia-reperfusion syndrome*. These complications are caused by toxic products that are released from the damaged tissue into the general circulation. Rhabdomyolysis is the primary concern and can lead to acute renal failure in severe cases. Thus, it is important to monitor for elevated serum creatine phosphokinase (CPK) and myoglobinuria when revascularization is performed. Hyperkalemia and acidosis may also occur as part of reperfusion syndrome as large amounts of potassium and acid are released from the ischemic muscle. Reperfusion syndrome can occur even with less severe ALI. Compartment syndrome is also a rare complication of reperfusion injury.

Areas Where You Can Get into Trouble

Mistaking the Diagnosis of ALI as a Neurological Condition

Patients with ALI can easily be mistaken as having an acute neurologic event, especially if the ischemia has led to significant paresthesias and muscle weakness. Spinal cord/nerve root impingement by metastases, herniated disks, spondylolisthesis, or trauma may present similarly to ALI. A careful motor/sensory exam is essential in addition to the pulse and Doppler vascular exam. The presence of normal pulses combined with a normal ABI in the affected extremity effectively rules out ALI.

Failing to Monitor for Elevated CPK and Myoglobinuria

Rhabdomyolysis is a potentially serious complication of reperfusion of a limb, with up to 20% of patients showing laboratory evidence of myoglobinuria. Of patients with CPK >5000 units/L, approximately half will develop acute kidney injury (AKI) caused by heme pigment, which precipitates in tubules leading to cast formation and direct toxic injury to proximal tubular cells. If rhabdomyolysis is suspected, prompt therapy with IV fluids (normal saline) should be started. IV fluids enhance renal perfusion and prevent ischemic injury while simultaneously increasing urine flow in order to limit intratubular cast formation and increase heme excretion. The prognosis for heme pigment-induced AKI is favorable with many patients returning to normal renal function.

Following Revascularization, the Patient Develops Peaked T Waves on the EKG

Peaked T waves are an early sign of hyperkalemia. It should be treated promptly with IV calcium gluconate which counteracts the effects of potassium on resting membrane potential to prevent arrhythmia. Insulin is then administered to drive potassium into cells via activation of the Na-K-ATPase pump. Glucose is given simultaneously to prevent hypoglycemia. High-dose inhaled albuterol may also be administered. While these interventions stabilize cell membranes and drive potassium into cells, further treatments are needed to remove potassium from the body. These include loop diuretics, potassium binders such as sodium polystyrene (Kayexalate), or dialysis in severe cases.

Following Revascularization, the Patient Develops a Swollen Leg

If ischemia-reperfusion syndrome leads to significant swelling of the extremity following revascularization, the patient can develop compartment syndrome which can have the same six Ps of ALI: pain, pallor, paralysis, pulselessness, paresthesia,

and poikilothermia. The major difference is that in compartment syndrome, pulselessness is a *late sign*. Monitoring leg compartments is essential in order to intervene early with urgent fasciotomy.

Platelet Count Drop 5 Days After Successful Reperfusion

Patients receiving heparin should have monitoring of the platelet count as they are at risk for heparin-induced thrombocytopenia (HIT). This is a paradoxically hypercoagulable state caused by antibodies formed against heparin as it is bound to platelet factor 4. HIT should be suspected if the platelet count drops by >50%, classically on day 5 of heparin exposure. HIT can cause a clot to form leading to recurrence of ALI. In the operating room, a clot from HIT will appear white, compared to the red clot from embolus. Heparin should immediately be stopped, and the patient switched to a direct thrombin inhibitor, such as argatroban.

Summary of Essentials

History and Physical

- Sudden onset of a cold painful pulseless extremity is suggestive of ALI.
- Ask about cardiac history (atrial fibrillation, recent MI) as these suggest cardioembolic source.
- Ask about claudication as this suggests thrombotic etiology from underlying atherosclerosis.
- Examine the heart for irregularly irregular rhythm (new atrial fibrillation).
- Examine for six Ps (pain, paresthesia, pallor, paralysis, pulselessness, and poikilothermia):
 - Pain is often the presenting symptom.
 - Pulselessness is the sine qua non.
 - Paralysis portends the worst prognosis.
- Examine contralateral nonischemic limb.
 - Signs of chronic peripheral arterial disease suggest a thrombotic cause.
 - Normal vascular exam suggests an embolic cause.

Pathophysiology

- Injury of skeletal muscle tissue begins at 3 hours and may be irreversible at 6 hours.

Diagnosis

- ALI is associated with motor/sensory deficits and must consider a primary neurologic etiology in the differential.

- Doppler ultrasound establishes diagnosis; CTA is a gold standard, is fast, and provides more information.
- The severity of ALI is determined by physical exam, primarily by the motor and sensory exam.

Management

- Immediately begin IV heparin and IV fluids, and place limb in a dependent position.
- Definitive treatment: catheter-directed thrombolysis or open surgical intervention.
- Intervention is time sensitive.
- Catheter-directed thrombolysis can take 24–48 hours to complete.
- Surgical revascularization is immediate.
- Amputation for irreversible disease (complete anesthesia and paralysis).

Complications

- Reperfusion syndrome with hyperkalemia, acidosis, rhabdomyolysis, acute renal failure, and compartment syndrome

Areas Where You Can Get into Trouble

- An acute neurologic event may be easily mistaken for ALI.
- Monitoring for elevated serum CPK and myoglobinuria is essential in order to prevent acute renal failure secondary to rhabdomyolysis after revascularization.

Areas of Controversy

- Surgical embolectomy is often considered the preferred treatment for embolic ALI, but contemporary research is challenging this notion.

Suggested Reading

- Campbell W, Ridler B, Szymanska T. Current management of acute leg ischaemia: results of an audit by the Vascular Surgical Society of Great Britain and Ireland. *Br J Surg.* 1998;85:1498–503.
- Norgren L, Hiatt WR, Dormandy JA, Nehler MR, Harris KA, Fowkes FG, Rutherford RB, TASC II Working Group. Inter-society consensus for the management of peripheral arterial disease. *Int Angiol.* 2007;26(2): 81–157. Review. PubMed PMID: 17489079.

Question Set: *Vascular*

Questions

1. A 62-year-old male presents to the physician with pain in his buttocks that comes on during his evening walks with his wife, forcing him to stop and rest. He also confides in you that he has been having difficulty maintaining an erection leading to marital problems. Physical exam is significant for absent femoral and distal pulses. What is the most likely diagnosis?
- (A) Leriche syndrome
 - (B) Acute occlusion of the infrarenal aorta
 - (C) Extensive atherosclerosis of the superficial femoral artery
 - (D) Spinal stenosis
 - (E) Bilateral hip osteoarthritis
2. A 59-year-old male comes to see his primary care physician endorsing a 10-month history of increasing bilateral calf pain with exercise. He initially only felt discomfort after walking six blocks, but now it occurs after only one block. The pain disappears with rest. His past medical history is significant for hypertension and hypercholesterolemia, for which he takes lisinopril and a statin. He has smoked two packs per day for the past 40 years. His physician orders a complete workup and decides the patient most likely is suffering from claudication secondary to peripheral arterial disease (PAD). Which of the following findings would be the best way to support the diagnosis of PAD?
- (A) History of pain in legs with exertion
 - (B) Diminished peripheral pulses on physical examination
 - (C) A combination of history and physical examination
 - (D) An ankle-brachial index (ABI) < 0.9
 - (E) Arteriographic evidence of atherosclerotic plaques
3. A 30-year-old male presents with a 4-month history of a painful right great toe. In addition, he states that when he walks about two blocks, his right foot hurts, and he has to stop to rest. He has a 20-pack-year smoking history. His pulse is 74/min, respirations are 18/min, and blood pressure is 126/80 mmHg. His total cholesterol is 160 mg/dL. His serum calcium is 9.4 mg/dL, and on physical examination, he has normal femoral and popliteal pulses bilaterally, but no palpable dorsalis pedis or posterior tibial pulses in either foot. The big toe is slightly bluish and tender to palpation. Which of the following is true about this condition?
- (A) It responds well to stenting.
 - (B) A bypass will be curative.
 - (C) Smoking cessation is the cornerstone of management.
 - (D) It is unlikely to be due to arterial occlusion.
 - (E) It most likely represents early atherosclerosis.
4. A 65-year-old male carpenter states that his left arm gets tired when he uses it at work, forcing him to stop and rest. In addition, he notes that when using his left arm, he experiences dizziness and vertigo. He has a long-standing history of smoking. Physical examination reveals normal brachial and radial pulses on the right but markedly decreased brachial and radial pulses on the left. In addition, there is an audible bruit just above his left clavicle. Which of the following is true about this condition?
- (A) The dizziness and vertigo are due to blood being diverted from the anterior brain circulation.
 - (B) Stenting of the left subclavian artery may be helpful.
 - (C) Systolic blood pressure measurements in right and left arms are likely to be the same.
 - (D) It is most likely due to an inflammatory arteritis.
 - (E) It more commonly affects the right arm.

9. A 55-year-old male comes to the physician complaining of bilateral leg pain with walking that is relieved by rest. He has a history of hypertension, hyperlipidemia, chronic obstructive pulmonary disease, and a 30-pack-year smoking history. On physical exam, his blood pressure is 139/79 mmHg, temperature is 37.8 °C, pulse is 89/min, and respirations are 16/min. Present behind both knees are small pulsatile masses. What is most strongly associated with this finding?
- (A) Aortic dissection
 - (B) Hypercoagulable state
 - (C) Degenerative joint disease (DJD)
 - (D) Abdominal aortic aneurysm (AAA)
 - (E) Thoracic aortic aneurysm
10. A 68-year-old male comes to the physician's office for a non-healing ulcer in his medial malleolus that has been present for several months. He has a past medical history significant for diabetes and hyperlipidemia. On physical exam, his temperature is 37.8 °C, pulse is 70/min, blood pressure is 133/79 mmHg, and respirations are 16/min. Physical exam is significant for pitting right leg edema up to the knee. The leg is warm, and the skin is shiny and has a reddish-brown appearance with several enlarged surface veins. The ulcer has granulation tissue without purulence. Dorsalis pedis pulses are 2+ bilaterally. He notes that the swelling is mild when waking up in the morning but worsens throughout the day. Which of the following is most likely to assist in healing the ulcer?
- (A) A compressive dressing impregnated with zinc oxide
 - (B) Diuretics
 - (C) A custom-fitted diabetic shoe
 - (D) Heparin
 - (E) Oral antibiotics
11. At a follow-up appointment 2 weeks after undergoing left carotid endarterectomy (CEA), it is observed that the patient's tongue deviates to the left when he is asked to stick his tongue out. Which of the following is the most likely explanation?
- (A) Perioperative stroke of the medulla
 - (B) Hematoma compressing the musculature of the oropharynx
 - (C) Injury to cranial nerve VII
 - (D) Injury of cranial nerve X
 - (E) Injury of cranial nerve XII
12. A 61-year-old man comes to the physician with an 8-month history of increasing bilateral calf pain during his morning walks. The pain disappears with rest. He reports that the last time he saw a doctor was 20 years ago. He has a 30-pack-year smoking history, but recently quit. His pulse is 68/min, respirations are 18/min, and blood pressure is 126/76 mmHg. His total cholesterol is 320 mg/dL. His doctor recommends that the patient starts a statin and aspirin to reduce the risk of adverse cardiac events. In addition, he recommends that the patient begins an exercise walking program. What would the addition of this intervention provide for the patient?
- (A) It will improve his overall cardiac health but will not improve his walking distance.
 - (B) It would be expected to result in an increase in his ankle-brachial index (ABI).
 - (C) It is less effective than administering a vasodilator.
 - (D) It can result in a doubling of his walking distance.
 - (E) It is contraindicated.
13. A 75-year-old male is recovering in the ICU from an open repair of a ruptured abdominal aortic aneurysm (rAAA). On postoperative day 1, he complains of abdominal pain and tenderness over the left lower quadrant, without rebound or guarding. On post-

18. A 71-year-old man comes in to the physician, along with his wife, and reports a 4-month history of increasing left calf pain with exercise. He works as a grocery store manager and describes having the pain every morning after he walks from his car in the parking lot to the grocery store. The pain disappears once he is able to sit down. He has smoked one pack per day for the past 50 years. His pulse is 88/min, respirations are 18/min, and blood pressure is 156/96 mmHg. His total cholesterol is 300 mg/dL. His right ankle-brachial index (ABI) is 0.7. His wife is very worried and asks the physician what his prognosis is. In patients with this condition, the 5-year survival is:
- (A) The same as that of age- and gender-matched controls without claudication
 - (B) Reduced primarily due to the risk of limb gangrene
 - (C) Reduced primarily due to lung cancer
 - (D) Reduced primarily due to coronary artery disease
 - (E) Reduced primarily due to stroke
19. A 61-year-old patient with coronary artery disease, diabetes, and hypertension presents to the emergency department with difficulty speaking and right-sided hemiparesis. His wife reports that he had multiple episodes a few days ago where he had difficulty speaking but they only lasted a few minutes. A CT scan of the head without contrast did not identify any hemorrhage in the brain. His systolic blood pressure is found to be 230 mmHg, and heart rate is 102/min. What is the most appropriate next step in management?
- (A) Labetalol
 - (B) Nimodipine
 - (C) Nitroglycerin
 - (D) Nitroprusside
 - (E) Hydralazine
20. A 67-year-old male smoker with a known abdominal aortic aneurysm (AAA) comes to the emergency department with the acute onset of flank pain. On physical exam, his blood pressure is 71/49 mmHg, pulse is 121/min, temperature is 37.8 °C, and respirations are 22/min. His abdominal exam reveals distention, a pulsatile abdominal mass, and diffuse tenderness without rebound. What is the most appropriate next step in management?
- (A) CT scan of the abdomen
 - (B) Exploratory laparotomy
 - (C) Transfusion of packed RBCs
 - (D) Abdominal ultrasound
 - (E) Diagnostic peritoneal lavage
21. A 56-year-old man is seen in the emergency department for onset of severe pain and numbness in his left leg that began 30 minutes ago. He has a past medical history significant for hypertension, diabetes, and hyperlipidemia. Physical exam reveals a temperature of 37.9 °C, blood pressure of 134/74 mmHg, pulse of 89/min, and respiratory rate of 16/min. The heart is irregularly irregular with no murmurs appreciated. On extremity exam, there is absent pulses in the left femoral, popliteal, and pedal arteries. On the right, all pulses are 2+. The left foot is cool to touch as compared to the right. Sensation to pinprick is decreased on the left dorsum of the foot compared to the right. What is the most likely etiology of these findings?
- (A) Arterial thrombosis
 - (B) Peripheral neuropathy
 - (C) Arterial embolism
 - (D) Cerebrovascular accident
 - (E) Venous thrombosis

as well as erectile dysfunction. Because of the rich collateral supply around the distal aorta and the chronic nature of the occlusion, the ABI typically drops by only 30% (to about 0.7). Thus, toe gangrene is rare. Patients with diabetes typically develop atherosclerosis more distally in the leg, in the superficial femoral and tibial arteries (not in the aorta). Acute aortic occlusion is a devastating, severe acute ischemia of both lower legs, which manifests by rapid onset of motor and sensory loss. It is seen following a large embolus from atrial fibrillation lodging at the distal aorta. The sudden onset does not permit adequate collateral enlargement. Untreated, it results in limb loss, massive acidosis, and death. Spinal stenosis compresses nerve roots, leading to generalized weakness of both legs that is worse with walking (D). Unlike claudication, it is usually relieved by leaning forward (such as over a shopping cart). Bilateral hip osteoarthritis more commonly affects older women and presents with tenderness on palpation of the hips (E).

- ✓ 2. Answer D
PAD is defined as an ABI <0.9 . The normal ABI ranges from 1 to 1.2. *Symptomatic* PAD can readily be diagnosed via history and physical examination, and in fact the classic history, combined with physical exam evidence of diminished pulses, is highly specific, but not sufficiently sensitive (C). Early PAD can be asymptomatic and is best detected by ABI. Arteriography is invasive and is thus reserved for patients who are to undergo an interventional procedure (E). The pulse exam is very subjective and cannot alone be relied upon to establish a diagnosis of PAD (B). History of pain in legs with exertion is not specific to PAD (A).
- ✓ 3. Answer C
Buerger's disease, also known as thromboangiitis obliterans, is a non-atherosclerotic vascular occlusive disease seen in young (<40 years), mostly male smokers. It predominantly involves the arteries in the leg below the knee (popliteal and tibial arteries) as well as hands. It also causes venous thrombosis. The cause is unknown. Stenting and surgical bypass (A–B) are ineffective as the occlusions involve the most distal arteries. The only effective treatment is smoking cessation. It is associated with high rates of amputation, especially if the patient continues smoking. The remaining answer choices (D–E) are not used in the management of Buerger's disease.
- ✓ 4. Answer B
Subclavian steal syndrome is due to an atherosclerotic stenosis or occlusion of the subclavian artery, most commonly on the left side (D–E). This leads to claudication symptoms of the affected arm and can be detected on physical examination based on diminished pulses, a significant (>20 mmHg) difference in arm blood pressure, and often a bruit above the clavicle (C). In addition, as the patient exercises, the arteries in the affected arm dilate, lowering resistance, so as to receive more blood. Since the occluded subclavian artery cannot increase blood flow, blood instead travels in a reverse fashion from the vertebral artery (the first branch off the subclavian) down to the arm, essentially stealing blood from the posterior brain circulation, leading to simultaneous symptoms of dizziness and vertigo (A).
- ✓ 5. Answer B
This patient has ischemic rest pain and a non-healing ulcer, both of which are manifestations of critical peripheral artery disease (PAD) that are considered limb threatening. The patient will likely progress to an amputation unless blood flow is improved. As such, the next step is to obtain arterial imaging of the lower extremities. This can be done by either CT angiography, MR angiography, or formal transfemoral arteriography in anticipation of either balloon angioplasty, stenting, or an arterial bypass. Tight glucose control will not help in achieving healing of an ischemic ulcer (C). Diabetic shoes are useful for ulcers that form over bony prominences in the setting of neuropathy (A). Although the patient has evidence of neuropathy, the location of the ulcer (distal toe), its appearance (lack of granulation tissue), absent pulse, and low ABI indicate that

of a prior deep vein thrombosis (DVT) that scars and damages valves, rendering them incompetent. The ensuing venous hypertension results in increased capillary pressure causing fluid and red and white blood cells to leak out of the capillaries. When the red cells break and lyse, they release the iron-containing hemosiderin and lead to the classic reddish-brown discoloration seen in stasis dermatitis. The pooling of blood leads to capillary damage and activation of an inflammatory process. The exact cause of ulceration in venous stasis is unclear but is likely a combination of leukocyte activation, endothelial damage, and intracellular edema. The cornerstone of treatment of venous stasis ulcers is compression therapy (A). The Unna boot is a compressive gauze that contains zinc oxide and calamine to promote wound healing. Diuretics do not benefit venous insufficiency (B). Diabetic shoes would be appropriate for a neuropathic ulcer, which would typically be located over a bony prominence (C). Heparin would be indicated for a DVT but not for chronic venous stasis (D). Venous stasis ulcers can become infected and require antibiotics; however, their routine use is not recommended (E).

✓ 11. Answer E

Cranial nerve deficits occur in about 8% of patients after CEA. In 80–90%, the deficit resolves within 6 months as the injury is due to nerve irritation from retraction and inflammation. In this case, the patient's tongue deviates to the left on protrusion, suggesting an injury to the left cranial nerve XII. This is the most common neuropathy following CEA. Perioperative stroke of the medulla would present with a larger constellation of symptoms (A). Hematoma is a concern in the immediate postoperative period and would be more likely to compromise the airway than a specific cranial nerve (B). Injury to the marginal mandibular branch of cranial nerve VII would cause a droop at the corner of the mouth (C). Cranial nerve X (D) transection would lead to voice hoarseness (D).

✓ 12. Answer D

The best medical management for sustained improvement in claudication is a walking program, which can double the walking distance (A, E). A supervised walking program, consisting of 40–50 minutes of walking 5 days per week is more effective than a non-supervised program. Contrary to common perception, a walking program does not appear to increase collateral blood flow nor does it reliably increase the ABI (B). The exact mechanism by which it improves claudication is not known, but possible mechanisms include improvements in endothelial function, skeletal muscle metabolism, and blood viscosity and a reduction in systemic inflammation. In response to peripheral arterial disease, the distal arterial bed undergoes significant vasodilation. As such, administering pure vasodilators are of no benefit (C).

✓ 13. Answer A

This patient is presenting with bowel ischemia secondary to compromised blood flow during open surgical repair of the rAAA. During aortic grafting, the inferior mesenteric artery is usually intentionally ligated, which rarely leads to inadequate colonic blood flow. The incidence of colonic ischemia is 7–27% for open repair of rAAA and 1–13% for elective AAA repair. *C. difficile* colitis presents with abdominal pain, fever, and watery diarrhea, typically following antibiotic use (B). Diverticulitis presents with abdominal pain and fever but not bloody diarrhea (C). IBD presents with bloody diarrhea, constipation, fecal incontinence, joint pain, and rash but is more chronic in nature (D). Colon cancer presents as occult gastrointestinal bleeding, weight loss, and a change in bowel habits (E).

✓ 14. Answer A

The most likely etiology of her neurologic deficits is transection of the common peroneal nerve at the fibular head. The most common presentation of peroneal nerve injury at the fibular neck is acute foot drop (difficulty dorsiflexing the foot against resistance or gravity) along with numbness of the dorsum of the foot. Compartment syndrome presents with the “six Ps”: pain (on passive motion), pallor, paresthesias,

✓ 20. Answer B

This patient is presenting with a ruptured abdominal aortic aneurysm (AAA). Hemodynamically unstable patients presenting with classic symptoms and signs of aortic rupture such as hypotension, flank pain, and a pulsatile mass should be taken emergently to the operating room (OR) for immediate control of hemorrhage. Additionally, a resuscitative endovascular balloon occlusion of the aorta (REBOA) can be placed as soon as the patient arrives to the hospital to temporarily control bleeding while the patient is transported to the operating room. Surgical intervention should not be delayed waiting for CT scan of the abdomen or transfusion of packed red blood cells (A, C). In fact, *permissive hypotension* is preferable to aggressive fluid resuscitation prior to the OR, as excessive fluids prior to aortic control may lead to more bleeding. In patients with symptomatic non-ruptured or ruptured AAA who are hemodynamically stable, CT scan of the abdomen can be obtained to assess for feasibility of endovascular repair. For patients who are unstable and are not previously known to have AAA and who do not have a palpable pulsatile mass, ultrasound may be performed quickly prior to abdominal laparotomy, to confirm the presence of AAA, but cannot determine rupture (D). Diagnostic peritoneal lavage is not appropriate to rule out a ruptured AAA. The rupture occurs retroperitoneally, so that a DPL would likely be negative (E).

✓ 21. Answer C

This patient is presenting with acute limb ischemia (ALI) given the pain, pulselessness, and paresthesias (recall the “six Ps”). The etiology of ALI includes thrombus formation (most likely due to long-standing peripheral arterial disease in the legs), embolization (most often from the heart), and trauma. The patient is presenting with an irregularly irregular heart rate, suggesting atrial fibrillation, which is the *most common source* of arterial embolism. Arterial thrombosis is another cause of ALI (A). Such patients often have a history of claudication and decreased pulses in the nonischemic leg. Peripheral neuropathy is an important cause of numbness in diabetic patients and would cause decreased sensation in a stocking glove pattern starting on the dorsum of the foot but would not account for the acute onset and absent pulses (B). Cerebral ischemia would cause a hemiparesis on the contralateral side and would not cause decreased pulses (D). Venous thrombosis of the deep veins would cause warmth, edema, and swelling in the affected leg (E).

✓ 22. Answer C

Patients who present with symptoms concerning for stroke should undergo a non-contrast CT scan of the brain to rule out intracranial hemorrhage. Once hemorrhage has been ruled out, consideration should be given for thrombolytic therapy for an ischemic stroke (intravenous if within 3 hours of symptom onset, intra-arterial if within 6 hours of onset). Doppler of the carotid artery, echocardiogram, ECG, or CT angiogram may be performed to evaluate for the cause of the stroke (carotid plaque vs. cardioembolic), but they are not part of the acute management of this patient (A–B, D–E).

✓ 23. Answer A

Warfarin is useful for the prevention of embolic events associated with atrial fibrillation and for the prevention of venous thrombotic events (such as deep venous thrombosis and pulmonary embolus). Since PAD is due to atherosclerosis and not due to embolus/thrombus, there is no evidence that warfarin benefits patients with PAD. Clopidogrel inhibits platelet aggregation by blocking activation of the glycoprotein IIb/IIIa pathway. In patients with PAD, it has been shown to reduce the combined endpoint of stroke, myocardial infarction, and acute limb ischemia (E). Given its high costs, its routine use in PAD is not recommended. Cilostazol is a quinolinone derivative that inhibits cellular phosphodiesterase. It inhibits platelet aggregation and is a direct arterial dilator. It inhibits vascular smooth muscle proliferation and improves the lipid profile (D). The exact mechanism by which it improves walking distance in patients with claudication is unclear. Aspirin does not directly improve claudication but is effective in reducing the risks of stroke and acute coronary events, which are common in

Supplementary Information

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